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Proceedings of the Symposium
Anais do Simpósio

The Pantanal: Scientific and Institutional Challenges in Management of a Large and Complex Wetland Ecosystem
O Pantanal: Desafios Científicos e Institucionais para a Gestão de um Extenso e Complexo Ecossistema de Planícies Úmidas

24th Annual Meeting of the Society of Wetlands Scientists, 8-13 June 2003, New Orleans, Louisiana

Edited by David J. Tazik, Antonio A. R. Ioris, and Stephen R. Collinsworth

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David J. Tazik

Environmental Laboratory
U.S. Army Engineer Research and Development Center
3909 Halls Ferry Road
Vicksburg, MS 39180-6199

Antonio A. R. Ioris

Department of Geography and Environment
University of Aberdeen, Scotland
SEPA, Erskine Court, Castle Business Park
Stirling, FK9 4TR, Scotland

Stephen R. Collinsworth

Coastal and Hydraulics Laboratory
U.S. Army Engineer Research and Development Center
3909 Halls Ferry Road
Vicksburg, MS 39180-6199

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ABSTRACT:
The Pantanal is one of the largest complexes of wetlands in the world, and has justifiably received increasing international attention. The Pantanal supports an extraordinary diversity and abundance of wildlife, making this "great swamp" a globally significant center of biological diversity. Critical to the maintenance of this natural diversity is the historical pattern of seasonal flooding that also affects economic activities in the region -- cattle ranching, commercial and sport fishing, and ecotourism. Agricultural development in the surrounding Cerrado and proposals to improve navigation along the Paraguay River are environmental issues of particular concern within the region.

While the socio-economic and ecological stability of the Pantanal depends largely on maintaining the integrity of the annual flood pulse, the hydro-ecology of the region is still poorly understood. The Pantanal Program was established by Brazil in 2001 to foster sustainable development in the Upper Paraguay River Basin. The long-term goal is to effectively employ natural capital in sustainable economic development that equally considers human, economic, and ecological dimensions.

The purpose of the symposium was to exchange information of mutual interest on innovative approaches to enhancing environmental sustainability in a large, complex ecosystem. A group of renowned scientists, resource managers, and public officials involved in the Pantanal Program were brought together to discuss the past, present, and future of stewardship in the Pantanal. The papers presented here address a full spectrum of ecological, socio-economic, and socio-political issues relevant to the Pantanal.

O Pantanal é uma das maiores e mais complexas áreas úmidas do mundo, a qual tem atraído crescente atenção internacional. A região pantaneira apresenta extraordinária diversidade biológica e exuberante vida silvestre, o que faz com que seja considerada como centro de biodiversidade de importância global. Suas características naturais, particularmente o regime sazonal de inundação, são críticas para a manutenção dessa diversidade biológica. Do mesmo modo, as atividades econômicas na região – tais como produção de gado, ecoturismo, pesca comercial e profissional – são diretamente influenciadas pelo regime hidrológico. Em anos recentes, a expansão agrícola em áreas vizinhas de cerrado e o incremento da navegação ao longo do Rio Paraguai são questões que despertam especial preocupação em razão dos impactos sobre a hidrologia pantaneira.

Apesar de a sócio-economia e a estabilidade ecológica do Pantanal dependerem, em grande medida, do pulso anual de cheias, a hidro-ecologia da região é ainda pouco compreendida. Como resposta do governo brasileiro a tais questões, o Programa Pantanal do Ministério do Meio Ambiente se iniciou em 2001 com o objetivo de fomentar o desenvolvimento sustentável da Bacia do Alto Rio Paraguai. Seu propósito é a promover um modelo de desenvolvimento de longo prazo da bacia hidrográfica que justa e apropriadamente atenda à dimensões humana, econômica e ecológica.

A proposta deste simpósio foi facilitar a troca de experiências em iniciativas inovadoras que possam contribuir para a sustentabilidade ambiental em extensos e complexos ecossistemas. Foi convidado um seleto grupo de renomados cientistas, gestores ambientais e representantes de governo para discutir o passado, o presente e o futuro da proteção do Pantanal. Os trabalhos aqui apresentados descrevem um amplo espectro de temas ecológicos, sócio-econômicos e sócio-políticos que são altamente relevantes para o Pantanal.

Contents

Preface vii

Dedication/*Dedicatória* viii

1—Introduction 1

References 3

2—Overview of the Paraguay Hydrographic Region 5

Abstract 5
Key words 5
General Characterization 6
Water Availability and Usage 8
Current Conflicts and Aims for the Future 10
References 12
About the Author 12

3—Pantanal: An Example of Conservation Through Use 13

Abstract 13
Key words 14
Introduction 14
Pantanal Features 15
Pantanal Economic Occupation 17
Threats to Biodiversity 19
Development Plans 21
Sustainable Development 23
Conclusion 24
References 24

4—Conflicts and Contradictions on the Occupation of the Pantanal Space 26

Abstract 26
Key words 27
Introduction 27
A Complex Social and Natural Landscape 27
Spatial and Socioeconomic Transformations 28
Institutional Responses and Failures 31
The Worst Case: Tragedies and Prospects for the Taquari 33
Conclusion 35
References 36
About the Author 38

5—An Approach to the Sustainable Use of the Natural Resources of the Pantanal, Upper Paraguay River Basin, Brazil 39

Abstract 39
Key words 40
Introduction 40
References 44
About the Author 45

6—Identification and Interaction Among Stakeholders of the Lake System Chacororé — Sinhá Mariana, Pantanal, Brazil 46

Abstract 46
Key words 47
Introduction 47
Study Area 48
Identification and Interest of Stakeholders in Lakes Chacororé and Sinhá Mariana 50
Interaction Among Stakeholders 52
Final Remarks 53
Acknowledgments 53
About the Authors 53
References 54

7—The Pantanal Ecology Project: Challenges and Progress of a Brazilian-German Scientific Collaboration 56

Abstract 56
Key words 57
Introduction 58
Study Area 59
Scientific Approach 60
Results of the PEP (Early work) 61
Interdisciplinary Studies (Subsequent work) 62
Erosion and sedimentation 63
Keystone and bioindicator species 64
Key habitats 64
Fisheries and tourism 66
Training of Personnel 67
Summary and Outlook 67
Acknowledgements 68
References 68
About the Authors 77

8—Pantanal Tri-National GIS and Remote Sensing Pilot Project Case Study for Bolivia, Brazil, and Paraguay 78

Abstract 78
Key words 79
Introduction 79
Project Background 81
Description of Results 82
Data Distribution 86
Conclusions 87

From the Pilot Project to the Comprehensive Upper Paraguay River Basin 87
References 87

9—Integrated River Management in the Pantanal: The Need for Decision Support Systems 88

Abstract 88
Key words 89
Introduction 90
Water Management in Brazil and the Upper Paraguay River Basin 90
Water Management in the Taquari River Basin 92
Present Situation and Project Objectives 93
Discussion 97
Acknowledgements 97
References 98
About the Author 99

Glossary of Acronyms 100

SF 298

List of Figures

Figure 1. The Paraguay Hydrographic Region 7

Figure 1. Location of Upper Paraguay River Basin (UPRB) and Brazilian Pantanal and its sub regions 16

Figure 2. Minimum, mean, and maximum Paraguay River levels at Ladario, MS, Brazil 17

Figure 3. Municipalities located within Pantanal and major surrounding towns 18

Figure 4. Taquari River flooded area 20

Figure 5. Road infrastructure plan for the Pantanal 22

Figure 1. Map of the Pantanal, Upper Paraguay River Basin, Brazil 41

Figure 2. Annual Paraguay River water level at Ladário City, South Pantanal, Mato Grosso 42

Figure 1. Study area, Lakes Chacororé and Sinhá Mariana and the Cuiabá River 49

Figure 2. Lakes Chacororé and Sinhá Mariana 50

Figure 3. Interaction among stakeholders in Lakes Chacororé and Sinhá Mariana 52

Figure 1. Map showing the position of the research site within Brazil and in the catchment area of the Paraguay River 59

Figure 2. The same area shown in Figure 1, but indicating (a) the connectivity of populations of the Pantanal and the Planalto, and (b) the export of pollution from the catchment area into the wetland 60

Figure 3. Goals of the first phase of the Pantanal Ecology Project, a Brazilian-German scientific collaboration..............................61

Figure 4. Goals of the second phase of the Pantanal Ecology Project, a Brazilian-German scientific collaboration 63

Figure 5. Master's and Bachelor's theses in ecology at the Federal University of Mato Grosso that were supported by the Pantanal Ecology Project 67

Figure 1. Study area, South America..80

Figure 2. Close-up view of study area...80

Figure 3. Seasonal flooded area/water level changes 82

Figure 4. Change detection differencing flood extent analysis 84

Figure 5. Ground control points for georeferencing of imagery................85

Figure 1. Structure and working fields of the Programa Pantanal.............92

Figure 2. Oscillations in water level in the Rio Paraguay in the last century...94

Figure 3. Possible spatial impact of the internal colonization on the Taquari River basin due to increased erosion......................96

List of Tables

Table 1. Pantanal General Features...16

Table 2. Animal Population Abundance within Pantanal 17

Table 3. Studies and Development Plans 21

Table 1. Stakeholders, Lakes Chacororé and Sinhá Mariana..................51

Table 1. Vegetation Change in the Bacia do Alto Taquari......................95

Preface

This effort was conducted by the Environmental Laboratory (EL) and the Coastal and Hydraulics Laboratory (CHL), U.S. Army Engineer Research and Development Center (ERDC), during 2003 under the Water Operations Technology Support (WOTS) Program with the assistance of the U.S. Army Southern Command (SOUTHCOM). Mr. Steve Collinsworth (CHL) served as our primary liaison with SOUTHCOM and the American Embassy--Brazil, providing technical and logitistical support to the symposium. This symposium would not have happened without his contributions. Ms. Leila C. Serpa and Major James Beuke, U.S. Military Liaison Office, American Embassy, Brazil, deserve special recognition for their efforts in facilitating the travel arrangements for the Brazilian participants. Many thanks also to Major Juan M. Saldivar, Jr., U.S. Army Exchange Officer, Brazil, for executing his mission as escort officer in a most efficient, effective, and professional manner. His outstanding effort contributed greatly to our success.

During the conduct of this activity, Dr. Beth Fleming was Acting Director, EL. At the time of this report, COL James R. Rowan, EN was Commander and Executive Director of ERDC. Dr. James R. Houston was Director.

Dedication/*Dedicatória*

This volume is dedicated to the memory of Dr. Osni Correa de Souza -- our friend and dedicated colleague.

1 Introduction

The Pantanal is one of the largest complexes of wetlands in the world. An order of magnitude larger than the existing Everglades of Florida, the Pantanal is inaccessible and largely in private ownership. It encompasses a significant portion of the Upper Paraguay Basin, primarily in Brazil, but also includes portions of Bolivia and Paraguay. The Pantanal is a key resource in South America that sustains the flow of the Paraguay River and has a major impact on the economy and ecology of the region (Gottgens et al. 2001). The Pantanal has received increased international attention with its designation by UNESCO as a Biosphere Reserve and World Heritage Site.

The Pantanal forms a complex mosaic of habitats that supports an extraordinary diversity and abundance of wildlife, making this "great swamp" a center of biological diversity of global significance. It is the last refuge for many of Brazil's threatened and endangered species, and is exceptionally abundant in waterfowl (Alho et al. 1988). The productivity and diversity of plant and animal life of the Pantanal is maintained by seasonal flooding.

The seasonal cycle of desiccation and inundation within the Pantanal results in flooded areas varying substantially over the annual cycle. This natural flooding pattern is a primary force controlling the structure and function of this and other floodplain ecosystems (e.g., Junk et al. 1989). This predictable pattern of disturbance and resulting spatio-temporal variability enhances and maintains biological diversity and productivity, and in turn, economic viability of the region.

Primary economic activities in the region include cattle ranching, commercial and sport fishing, and ecotourism. A variety of environmental problems are associated with these activities (Alho et al. 1988, da Silva 2000). Erosion and sedimentation associated with an increase in cattle grazing and row crop production in the uplands of the Cerrado surrounding the Pantanal are of particular note. This has led to an altered pattern of flooding in large areas of the Pantanal, notably in the Taquari River basin. Other human impact issues include mining, illegal fishing and hunting, deforestation, construction of raised roads and dikes.

Most recently, the proposed Hydrovia, or Paraguay-Parana Waterways, Project has created considerable concern among the scientific and conservation communities interested in the Pantanal (Gottgens et al. 2001). The goal of the project is to increase large barge navigation on the Paraguay River especially

during periods of low flow. It has the potential to have the most profound impact on the whole of the Pantanal. Hamilton (1999), for example, has demonstrated that even a relatively small change in the channel capacity of the Paraguay River will result in dramatic change in the extent of annual inundation, and, in turn, on the hydro-ecology of the entire floodplain ecosystem. Although the project is on hold, numerous small navigation and dredging projects are being implemented. Over time, these may cause more problems than a comprehensively planned project (Gottgens et al. 2001).

Clearly, the socio-economic and ecological stability of the Pantanal depends largely on maintaining the integrity of the annual flood pulse. Unfortunately, the hydro-ecology of the region is still poorly understood.

The Pantanal Program was established in 2001 as a key strategic initiative of the Federal Republic of Brazil (Inter-American Development Bank 2000). The total authorized budget is $400M over eight years, with half to be provided by the Inter-American Development Bank and the remainder by Brazilian sources. The Brazilian Ministry of the Environment manages the program. The States of Mato Grosso and Mato Grosso do Sul carry it out. This program is intended to foster sustainable development in the Upper Paraguay River Basin. The most immediate goal is to stabilize environmental quality across the Pantanal by supporting reforms in natural resource management and conservation, and by restoring key watersheds. The long-term goal is to effectively employ natural capital in sustainable economic development that equally considers human, economic, and ecological dimensions. The five major components of the program include:

- Watershed management.
- Urban development.
- Establishment and rehabilitation of parkways.
- Promotion of sustainable development activities.
- Institutional strengthening.

The purpose of the symposium was to exchange information of mutual interest on innovative approaches to enhancing environmental sustainability in large, complex ecosystems. The intent was to transfer technologies and information that will aid the participants in developing sustainable approaches to economic development in the Pantanal region of Brazil. The symposium was held in conjunction with the annual meeting of the Society of Wetland Scientists, providing the group a chance to discuss the challenges and opportunities they face in implementing the Pantanal Program, and to further interact with a group of wetland scientists who could offer valuable insights and assistance.

The symposium brought together a group of renowned scientists, resource managers, and public officials to discuss the past, present, and future of stewardship in the Pantanal. Lessons learned were brought to light, giving participants an opportunity to assess implications for wetlands stewardship nationally and internationally.

In his *Overview of the Paraguay Hydrographic Region*, Dr. Marco A. Palermo describes the region, including socio-economic aspects, discusses water availability and usage and basic sanitation indicators, and summarizes current water resource issues and goals for the future. In *Pantanal: An Example of Conservation Through Use,* Dr. Mario Dantas argues that the Pantanal is among the best conserved ecosystems in Brazil as a result of the historical system of cattle grazing, whereas the main threat to the system is from poor land use practices in the Planalto surrounding the region. Mr. Antonio A.R. Ioris delves into the socio-political issues surrounding the Pantanal in his paper, *Conflicts and Contradictions on the Occupation of the Pantanal Space*. He concludes that environmental sustainability in the region depends not only on sound knowledge and institutions, but also on effective means of conflict. In her paper, *An Approach to the Sustainable Use of the Natural Resources of the Pantanal*, Dr. Emiko Resendede Resende gives a very nice general description of the Pantanal and explains the role of the flood pulse concept as the primary ecological process contributing to resource diversity and abundance. Dr. Carolina Joana da Silva addresses human dimensions in her paper, *Identification and Interaction Among Stakeholders of the Lake System Chacorore—Sinha Mariana*. Her results show that different interests regarding the Pantanal range from international down to local on-site. The number and diversity of interests increase at the local on-site level, especially as regards fishing. In *The Pantanal Ecology Project: Challenges and Progress of a Brazilian—German Scientific Collaboration*, Dr. Catia Nunes da Cunha and her co-workers illustrate much of the work that has been accomplished under this important initiative. They emphasize the need for a solid scientific basis for decision making, and an interdisciplinary approach based on the flood pulse concept. Standards and guidelines for delivering a GIS database, evaluating land-use and conservation planning needs, identifying pilot project areas, establishing data priorities, and formulating partnerships are described in the paper presented by Kristine Kuhlman and her co-workers, *Pantanal Tri-National GIS and Remote Sensing Pilot Project Case Study for Bolivia, Brazil, and Paraguay*. Dr. Rob H.G. Jongman addresses environmental issues associated with the Taquari River basin, which represents one of the major erosive areas of the highlands surrounding the Pantanal. In *Integrated River Management in the Pantanal: The Need for Decision Support Systems*, he proposes development of a river management decision support system similar to that developed for the Rhine Catchment in Europe. Finally, Dr. Osni Corea de Souza presented his ideas on the Rio Taquari in his paper, *Hydrological Changes Along the Taquari Alluvial Fan in the Pantanal Wetland.* A paper was not available at this writing due to the untimely death of Dr. De Souza. Results of his work can be found in de Souza et al. (2002).

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2 Overview of the Paraguay Hydrographic Region (*Caracterização Geral da Região Hidrográfica do Rio Paraguai*)

Palermo, Marco A.
Consultant Engineer, National Water Agency of Brazil (ANA), Av. São Luís, 50, cj. 211[A]
São Paulo- SP, Brazil, CEP 01046-000 e-mail: *palermo@altamisa.com.br*

Abstract (*Resumo*)

The Paraguay Hydrographic Region is important within the national context as it includes the Pantanal, one of the largest extensions of freshwater wetlands on the planet, declared a National Heritage Site by the Federal Constitution of 1988 and a Biosphere Reserve by UNESCO in 2000. This overview of the region presents data on socio-economic aspects, water availability and usage and basic sanitation indicators, as well as a brief summary of the current issues regarding the use of water resources and goals for the future.

A Bacia Hidrográfica do Rio Paraguai é importante no contexto nacional pois compreende o Pantanal, uma das maiores superfícies de áreas alagadas por águas doces do mundo, tendo sido declarada patrimônio nacional pela Constituição de 1988 e reserva da biosfera pela UNESCO em 2000. Este artigo apresenta uma visão sumária e global da Bacia sobre os aspectos sócio-econômicos, de demanda e disponibilidade hídrica, e de saneamento, bem como uma síntese dos atuais temas em discussão sobre o uso dos recursos hídricos e as perspectivas futuras.

Key Words

Pantanal, Paraguay River, wetland, socio-economic indicators (*Pantanal, Rio Paraguai, área úmida, indicadores sócio-econômicos*)

General Characterization

The Paraguay River originates in Brazilian territory and its hydrographic basin covers an area of 1,095,000 km^2; 34 percent in Brazil and the remainder in Argentina, Bolivia, and Paraguay. (Data and information presented below come largely from the National Water Authority, Brazil (ANA) (2002, 2003.) The mean river discharge in the region is 1,340 m^3/s, which represents 1 percent of the total river discharge in the country. The upper section of the hydrographic region comprises an area of 363,592 km^2 in Brazil (80 percent of the total area) and also encompasses the Bolivian and Paraguayan territories. The Paraguay Hydrographic Region in Brazilian territory (4.3 percent of national territory) encompasses parts of the states of Mato Grosso do Sul (51.8 percent) and Mato Grosso (48.2 percent) (Figure 1).

Approximately 1.8 million people live in the region (1 percent of the population of Brazil), 85.7 percent in urban areas. The towns of Cuiabá-MT (483,000 inhabitants), Várzea Grande-MT (215,000 inhabitants), Rondonópolis-MT (150,000 inhabitants), Corumbá-MS (95,000 inhabitants) and Cáceres-MT (85,000 inhabitants) are the largest population centers. The Paraguay Hydrographic Region comprises 44 municipalities in Mato Grosso and 25 municipalities in Mato Grosso do Sul.

The majority of the population is concentrated in the sub-basins of the Cuiabá and Alto Paraguai Rivers (59 percent of the basin's total population). The demographic density of the hydrographic region is 5.1 inhabitants/km^2, much lower than the demographic density of the country as a whole (19.8 inhabitants/km^2).

The hydrographic region does not present great climatic variability, being almost entirely classified as a Tropical Savanna climate. Average annual temperatures vary between 22.5 and 26.5 °C, the hottest month being November (average of 27 °C) and the coldest month July (average of 21 °C).

Average annual rainfall is 1,396 mm, varying between 800 and 1,600 mm, the highest rainfall being recorded in the tableland areas (called Planalto). The rainy season is from October to April and the dry season occurs in the remaining months. Total annual average evaporation is 1,280 mm, with the highest levels occurring in August, when highest insolation levels are recorded.

The Paraguay Hydrographic Region includes both Savanna and Wetlands, and transition zones between these two biomes. The predominant vegetation is Shrub Savanna and Woodland Savanna.

In terms of socio-economic indicators, the infant mortality rate (per 1,000 births) in the states of the region is 27.03 in Mato Grosso and 23.98 in Mato Grosso do Sul, lower than the national average (33.55).

The gross domestic product (GDP) per capita is US$1,565 in Mato Grosso and US$1,752 in Mato Grosso do Sul, lower than the national average for Brazil (US$1,913). The GDP of the region represented 1.2 percent of the national GDP in 1996.

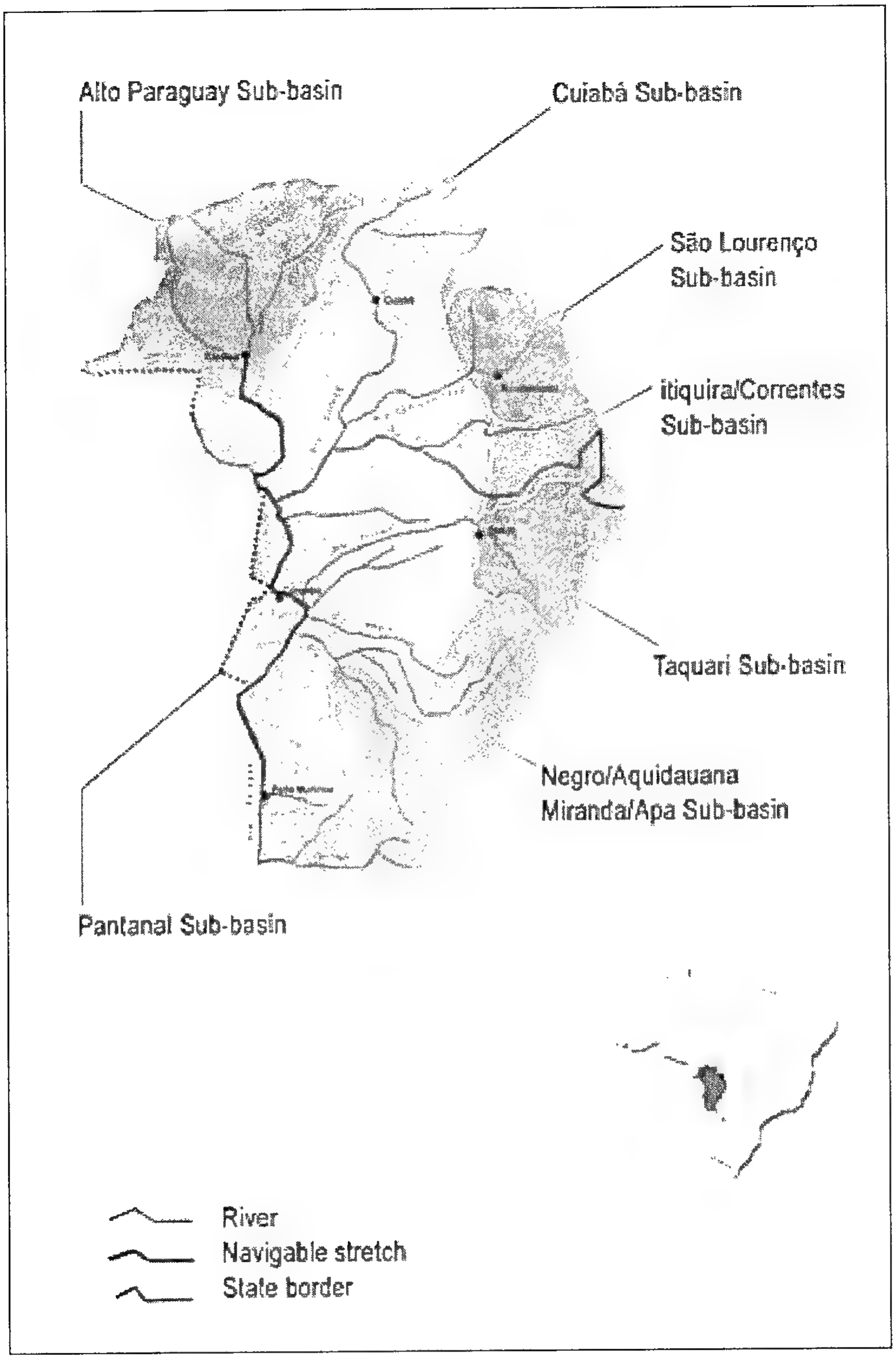

Figure 1. The Paraguay Hydrographic Region

The human development index (HDI) in the states within the hydrographic region is 0.767 in Mato Grosso and 0.848 in Mato Grosso do Sul, only the latter being greater than the national HDI (0.830). The states of Mato Grosso and Mato Grosso do Sul are ranked 15th and 5th, respectively, in the HDI ranking of the Brazilian states.

In terms of basic sanitation indicators, the percentages of urban households with sewage collection facilities are 16.9 percent in Mato Grosso and 7.7 percent in Mato Grosso do Sul, far lower than the national average (52.5 percent). The percentage of urban households with internal plumbing, served by public water supplies is 72.9 percent in Mato Grosso and 88.8 percent in Mato Grosso do Sul. The percentages of urban sewage treatment are 14 percent in Mato Grosso and 15 percent in Mato Grosso do Sul, both below the national average. Freshwater is mainly supplied by surface water springs.

Extensive cattle farming is the main economic activity of the region, utilizing the naturally occurring fields in the plains of the Pantanal. Large areas of savanna in the upper region (Planalto) were deforested and cleared to establish agro-industries, in particular for the production of soybeans for export. Open-pit mining of gold, diamonds, limestone, iron, and manganese is also an important activity, particularly in the Planalto region. Tourism (sport fishing, and eco-tourism) is an important economic activity in the Pantanal (approximately 260 species of fish exist in the region).

Since the 1970's the expansion of cattle farming and soybean crops in areas of the Planalto has increased deforestation and erosion. Due to the fact that various rivers in the region (e.g., Taquari and São Lourenço Rivers) have a high capacity to transport sediment, the sediment deposits have increased in the Pantanal with subsequent siltation and sandbar formation in the rivers.

Water Availability and Usage

The Paraguay River originates in the Chapada dos Parecis in Mato Grosso, and along its course southwards it receives various important tributaries along its left banks, in particular the Cuiabá, São Lourenço, Taquari, Miranda, and Negro Rivers. The hydrographic region is comprised of two main areas and six sub-basins:

- Planalto (lands over 200 m high). Main sub-basins: Alto Paraguay, Cuiabá, São Lourenço, Negro/Aquidauana/Miranda/Apa, Taquari and Itiquira/Correntes (total area:215,963 km^2).

- Pantanal and Lowlands (lands below 200 m high). Have low drainage capacity and are subject to heavy flooding, 65 percent of this area is in the state of Mato Grosso do Sul and 35 percent in Mato Grosso (total area: 147,629 km^2).

The Pantanal functions as a vast reservoir that retains a large part of the water draining from the Planalto and regulates the runoff of the Paraguay River. The poor drainage of the rivers and lakes that form in the Pantanal and the climate in the region cause approximately 60 percent of the water coming from the Planalto to be lost to evaporation.

The rivers of the region have the capacity to bear the average discharge levels, but during the floods, a period in which this capacity is exceeded,

extensive areas of the plains are flooded, forming temporary lakes over an area of up to 100,000 km^2. From May onwards the waters start to diminish slowly, the period known as the "vazante" (low water levels). When the soil dries out again, a fine layer of nutrients is left behind, which makes the topsoil highly fertile and promotes the growth of native grasses that serve to feed over 3 million head of cattle.

The mean fluvial discharge of the Paraguay River is 1,340 m^3/s (1 percent of the total for the country). The hydrographic region presents a very low specific discharge (just 4 $l/s/km^2$) as a result of high evaporation losses in the Pantanal region.

The sub-basins of the Planalto have specific discharge rates between 12 and 20 $l/s/km^2$ (with the exception of the Negro/Aquidauana/Miranda/Apa sub-basin), indicating relatively well-distributed water availability. The mean specific discharge rate in the Planalto region is 12.8 $l/s/km^2$. The specific discharge of the Pantanal is just 0.87 $l/s/km^2$, due to the small slope of the region that retains a large part of the volume of water that drains from the sub-basins of the Planalto.

With regard to groundwater, the majority of the hydrographic region has porous aquifers associated with non-consolidated sediments that coat the more ancient rocks, with groundwater wells having an average depth of 50 m and discharge rates exceeding 30,000 l/h. In the Pantanal, groundwater is abundant, but problems may arise in terms of the quality of the water (brackish or with a high iron content). In the Planalto, the quality of water is good, although it may have quantitative restrictions.

The human demand is 4.02 m^3/s (7 percent of the total demand) and is concentrated in the sub-basin of the Cuiabá River, where the metropolitan region of Cuiabá/Várzea Grande faces supply problems, due to the pollution of the rivers caused by the lack of sewage treatment facilities.

The industrial demand is 1.09 m^3/s (2 percent of the total demand), the highest demands being recorded in the sub-basin of the Cuiabá River. Approximately 75 percent of industrial water requirements are met by surface sources that supply the public systems, and consume 5 percent of the total production of treated water. The main industrial sector is the food processing industry, which generates effluents with high levels of organic matter.

The livestock demand is 10.29 m^3/s (18 percent of the total demand), the highest demands occurring in the Negro/Aquidauana/Miranda/Apa sub-basin, where the largest populations of cattle and sheep are concentrated. The irrigation demand is 40.81 m^3/s, mostly concentrated in the sub-basin of the Miranda River for rice cultivation.

The total water demand in the Paraguay hydrographic region is 56 m^3/s (2.5 percent of the total for the country), of which 73 percent is for irrigation, 18 percent for livestock, 7 percent for human use, and 2 percent for industrial use.

Due to its physiographical configuration, the hydrographic region has little potential for power generation. At present, only small-scale hydroelectric power generation exists (less than 20 mW), and it is restricted to the areas of the Planalto. The construction of five thermoelectric plants in the states of Mato Grosso and Mato Grosso do Sul, using gas from Bolivia, will increase the power-generating capacity.

Commercial river travel in the Brazilian stretch of the Paraguay River takes place on a limited scale. Sedimentation within tributaries of the Paraguay River alters riverbed course, thereby hampering commercial navigation. A proposed project includes heavy dredging, meander removal, and lining 3,400 km of the Paraguay River, forming a deeper navigable channel. However, due to the environmental impact of this proposal, the federal government is studying alternatives with lower impacts to the waterway.

For domestic wastewater, the potential urban organic load is 85 tons BOD/day (1 percent of the total of the country), which is concentrated in the vicinity of the Cuiabá/Várzea Grande metropolitan region.

During the flood season, the quality of the water deteriorates in some stretches of the river, due to the accumulation of vegetation and sediments that create a higher oxygen demand. During this period, the water tends to have a low oxygen content producing inadequate conditions for the preservation of aquatic life.

Water pollution in the region results from poor soil management practices in areas of soybean production and cattle ranching areas of the Planalto. The increase in deforestation and clearing, and the subsequent erosion in these areas, have been causing silting up and sand bar formation in the rivers in the Pantanal. This process has been altering the courses of the rivers and increasing the flood period, which has affected the productivity of the flooded areas and commercial navigation, as, for example, on the Taquari River.

Another source of water, sediment, and fish contamination is the mercury released in gold-mining activities, particularly in the state of Mato Grosso, and contamination from pesticides used in the crops of the Planalto.

Among the critical issues, the most notable are the floods that are a natural process of the hydrographic region and that commonly occur in the Pantanal region during several months of the year, during the rainy season (October-April). However, due to the sediment deposition observed since the 1970s, the flood period has been expanding and productive properties are remaining flooded for most of the year, damaging the crops. Some landowners have constructed levees to reduce the flooded areas, which, in turn, have impacted the fluvial morphology.

Current Conflicts and Aims for the Future

It is estimated that by 2015 the population of the hydrographic region will reach 2,250,000 inhabitants, of which 90 percent will be living in urban areas. As

such, the tendency is for the problems of organic pollution of the rivers in the vicinity of major urban centers, such as the Cuiabá River, to worsen. The expansion of the agricultural areas in the Planalto is also expected to put further pressure on the water resources, unless appropriate management measures are adopted.

Tourism, related to sport fishing, has increased dramatically in the Pantanal region, which could be adversely affected if actions are not taken to protect the water resources.

Major conflicts regarding the use of water resources tend to increase in the eastern portion of the hydrographic region, pollution being the main factor generating concern. Among the current conflicts, the following are most marked:

- Inadequate use of the soil in the Planalto (soy bean crops and extensive cattle farming), resulting in increased deforestation and erosion, causing silting-up and sandbar formation in the rivers of the Pantanal.
- Navigation of large convoys on the Paraguay River, causing degradation of the vegetation on the banks and along the river.
- Mercury contamination of the water, sediment, and fish and bird life due to gold-mining activities, particularly in the state of Mato Grosso, which also causes the natural course of the rivers to be altered.
- Contamination of water and sediments by pesticides used in annual crop production in the Planalto region.

Among the priority actions to be taken in the Paraguay hydrographic region are:

- Define and implement a program of erosion control and soil management in the Planalto aiming to recover the silted rivers.
- Improve the licensing and control of mining activities as recuperation of degraded areas.
- Implement municipal wastewater treatment systems in the main urban centers.
- Regulate the river navigation and control the traffic of convoys on the Paraguay River.
- Consolidate and extend the existing hydrological monitoring networks, including the real-time flood forecasting network.
- Resolve the problem of mercury contamination of the water, sediment, fish and bird life caused by mining activities, particularly in the state of Mato Grosso.
- Define a strategy to minimize the contamination of water by pesticides.

- Control the expansion of new croplands in the Planalto.
- Conduct technical evaluation studies on the major regional infrastructure projects planned: Upper Paraguay Waterway, Corumbá steel plant, projects to expand cattle farming and grain croplands.

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About the Author

Marco Antonio Palermo, PhD, University of São Paulo in the field of Water Resources Engineering, MSc, University of São Paulo in Hydraulics Works, Hydrologist by the International Institute for Environmental Engineering, Delft, The Netherlands. Dr. Palermo is the director of the Upper Tietê River Basin Watershed Agency and has served as a consulting engineer to the Organization of the American States. The author has worked as senior specialist at the National Water Authority (ANA) in projects related to wetlands (Pantanal) and also for the State of São Paulo Water Agency (DAEE) for 13 years as a hydrologist.

3 Pantanal: An Example of Conservation Through Use (*O Pantanal Brasileiro: Um Exemplo de Conservação Através Do Uso*)

Mário Dantas
Ecologist, Universidade Vale do Rio Verde de Três Corações (UNINCOR), Rua Coronel Bekchior Pimenta de Abreu 97, Minas Gras, Brazil e-mail: *clan@unincor.br*

Abstract

The Brazilian Pantanal has been used for cattle ranching for more than two centuries, after the decline of gold mining in the region. Gold mining was the attraction for the first colonizers but the open fields covered by native grasses offered the chance to introduce meat cattle into the region. This economic activity has been implemented through an extensive production system in large areas. Initially only mineral salt was used; other technologies such as reproduction season, vaccination, intestinal parasite control, and introduction of cultivated grass in small areas have been implemented in the region, while keeping the biodiversity and the production system as natural as possible. Consequently, the Pantanal is actually the best-conserved ecosystem complex in the world in terms of biodiversity and ecosystem functioning. The main threat is from the Planalto surrounding the region. Agriculture and cattle ranching with cultivated pastures developed in those areas have caused erosion and water body sedimentation within the Pantanal. Sport fishing has seriously impacted the icthyofauna. Other impacts include road and dam construction, the division of large farms into smaller parcels, and an influx of people with a different philosophy. The pantaneiros are responsible for the conservation that has occurred and they are very proud of that. On the other hand, governmental actions to improve regional conservation through creation of national parks and designing and implementing an action plan for biodiversity conservation are very positive. It is extremely important to maintain the pantaneiro tradition and to keep the production system consistent with the natural ecology of the region.

O Pantanal brasileiro tem sido usado para produção pecuária por mais de dois séculos. A mineração de ouro serviu de atração para os primeiros colonizadores, porém, com o declínio do garimpo na região, os campos de gramíneas ofereceram a chance de introduzir fazendas de gado de corte. Esta atividade econômica foi implementada através de um sistema de produção extensivo onde se ministrava ao gado basicamente sal mineral. Havia restrito uso de outras tecnologias intensivas de produção, tais como estação de monta, vacinação, controle de parasitas intestinais e pastagens cultivadas em pequenas áreas. Desse modo, manteve-se a biodiversidade e o sistema de produção tão natural quanto possível. A conseqüência é que o Pantanal é atualmente o complexo de ecossistemas melhor conservado no mundo em termos de biodiversidade e integridade ambiental. Os pantaneiros são os responsáveis por essa conservação, havendo grande consciência e orgulho a esse respeito. Há novas ameaças, porém, principalmente vindo do planalto situado em torno do Pantanal, devido à agricultura e à pecuária desenvolvidas nessas áreas, o que tem causado erosão do solo e sedimentação dos corpos d'água que adentram o Pantanal. Atividades de pesca esportiva têm também afetado seriamente a ictiofauna. Outras ameaças têm sido a construção de estradas ou barragens e a divisão de grandes fazendas, bem como a chegada de novas pessoas com posturas conflitantes. Por outro lado, ações governamentais voltadas para a conservação da região, como a criação de parques nacionais e a implementação de planos para conservação da biodiversidade, têm sido muito positivas. É importante que se mantenha a tradição pantaneira e um sistema de produção adaptado à natureza.

Key Words

Pantanal, wetlands, wildlife, biodiversity, land use (*Pantanal, áreas úmidas, vida silvestre, biodiversidade, uso do solo*)

Introduction

The Pantanal is one of the world's largest continuous wetlands, where flocks of wading birds and Neotropical mammals as well as hundreds of grasses, forbs, and browsing species live on a mosaic of rivers, floodplains, channels, ponds, flooded grasslands, Cerrado, Savannah, and some dry forest on ancient levees. This region has been used as rangeland for more than two centuries, having been the main cattle breeding area of Central Brazil. This complex of ecosystems, the ecological region of Brazil best conserved, is a national patrimony according to the Brazilian Constitution and was declared a biosphere reserve by the United Nations Education Scientific and Cultural Organization (UNESCO). This region was developed by ranchers and the first colonizers in the easiest way at the time, cattle breeding in an extensive system and occupying large areas. This activity became the main economic activity of the region for many years. More recently, it appears that sport fishing and other non-traditional activities have increased in importance.

Pantanal Features

The Pantanal region covers an area of about 200,000 km^2, with 80 to 85 percent of this area in Brazil, 10 to 15 percent belonging to Bolivia, and an estimated 5 percent falling within the borders of Paraguay. The dimensions of the Brazilian Pantanal encompass an area of 138,183 km^2. It is located within the Upper Paraguay River Basin, which occupies 361,666 km^2 (Figure 1).

The Pantanal was formed approximately 65 million years ago when the uplift of the Andes caused the collapse of this region, initiating the process of sedimentation. Therefore, soils in the Pantanal are alluvial, sandy (65 percent), hydromorphic (92 percent), and with low fertility (72 percent). The climate is hot and humid in the summer and mild and dry in winter; precipitation varies from 1,000 to 1,400 mm, concentrated from December to March (Table 1).

The water regime resulting in flood and dry periods is a very important characteristic of Pantanal where the water commands the life. Sometimes there is an excess of water; sometimes there is a lack. The data collected by the Brazilian Navy at Ladario's Base show fluctuations of the Paraguay River level through one century and do not show a clear increase in humid or dry periods, but suggest long periods of alternating high and low floods (Figure 2).

Cerrado or Savannah is the dominant vegetation type, with grassland (open fields) dominating lower areas, which are affected by water during certain times of the year. Riparian forest and forest or arboreal vegetation are observed in higher areas. About 1,800 plant species have been listed, including about 200 species of grasses and 100 herbaceous legumes and many others, including timber, medical, fructiferous, and others.

The Pantanal supports over 90 species of mammals, 162 reptiles, 700 birds, 45 amphibians, about 300 fishes and thousands of insects. Some of those species present healthy populations (e.g., caiman (*Caiman crocodilus yacare*) and capybara (*Hydrochaeris hydrochaeris*)) (Table 2).

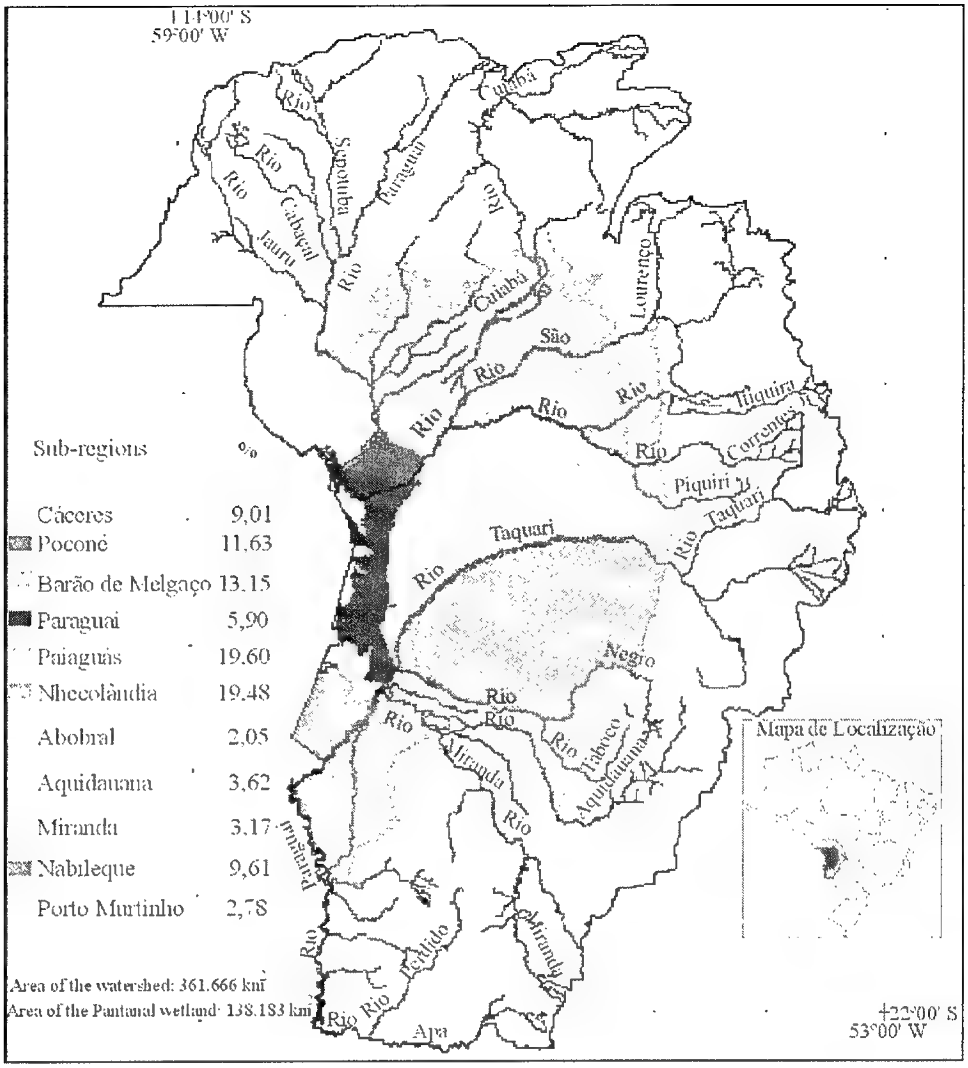

Figure 1. Location of Upper Paraguay River Basin (UPRB) and Brazilian Pantanal and its sub regions (Silva and Abdon 1998)

Table 1
Pantanal General Features

Sub regions	11
Townships	16
Geological age	65 million years
Average temperature	25°C
Rainfall	1,000 – 1,400 mm
Humidity	65-85 percent
Declivity	N-S – 1.5 cm/km E-W 2.5 cm/km
Ranches	4,094

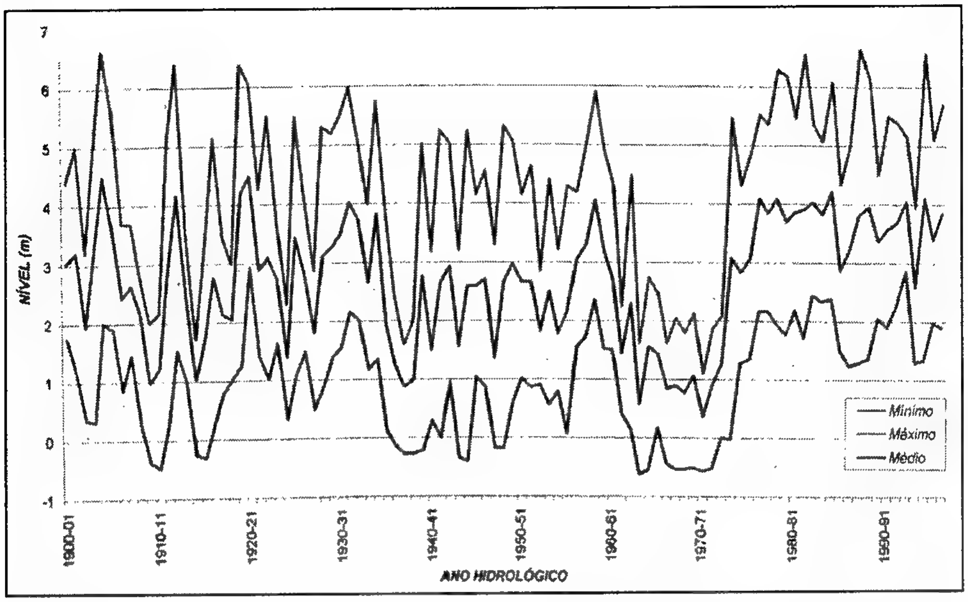

Figure 2. Minimum, mean, and maximum Paraguay River levels at Ladario, MS, Brazil (Source: EMBRAPA-CPAP)

Table 2
Animal Population Abundance within Pantanal

Species	**Estimated Population Size**
Caimans (*Caiman crocodilus yacare*)	> 3 million
Capybaras (*Hydrochaeris hydrochaeris*)	700,000
Marsh Deer (*Blastocerus dichotomus*)	36,000
Pampas Deer (*Ozotocerus bezoarticus*)	41,000 groups (1-7/group)
Wild Boar (*Sus scrofa*)	10,000 groups (>10/group)
Giant Anteater (*Myrmecophaga tridactyla*)	5,000
Tuiuiu Stork (*Jabiru mycteria*)	15,000 active nests
Asian Water Buffalo (*Bubalus bubalis*)	5,000
Cattle (*Bos Taurus*)	3 million

Pantanal Economic Occupation

Human population densities inside the Pantanal are very low, approximately 30,000. Towns (e.g., the capitals of the two states and others) surround the plain (Figure 3). Immigration to the area was stimulated in the beginning by the search for gold and other minerals. The colonizers went up the rivers and established some settlements in the plateau, which later developed into important towns like Cuiaba.

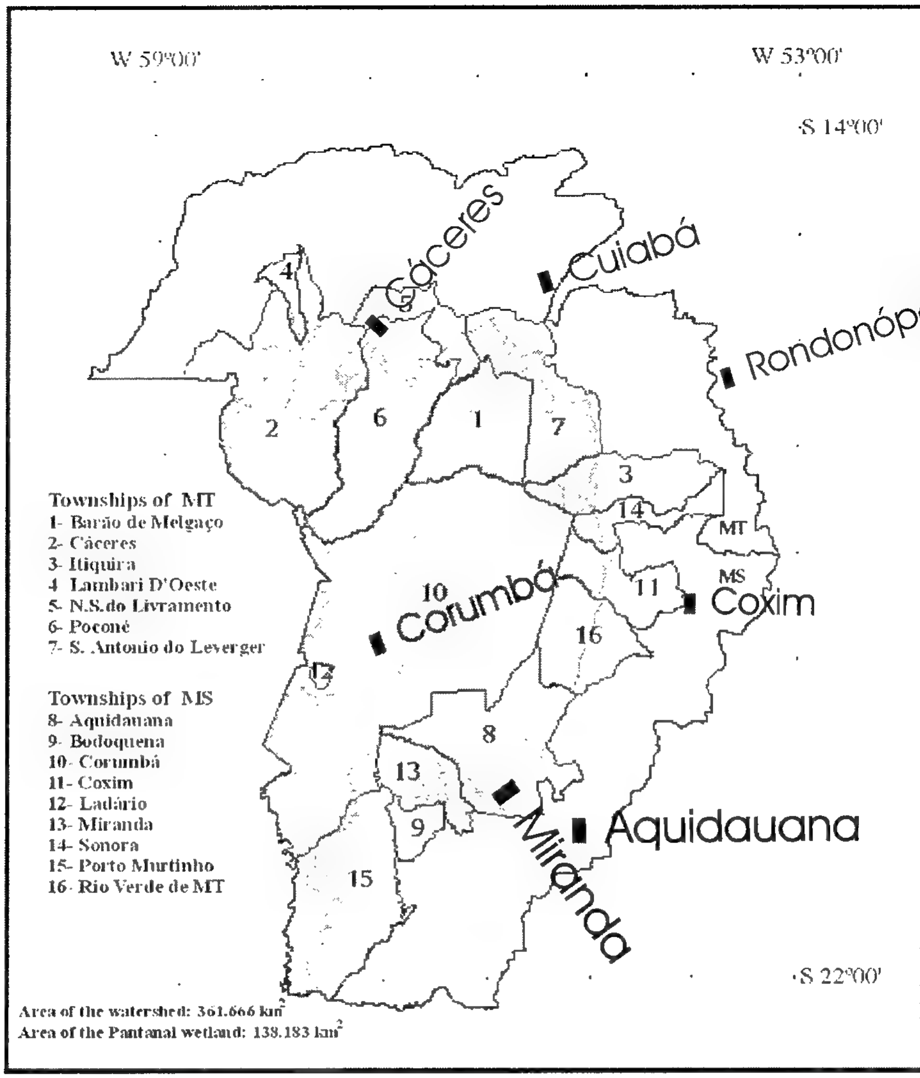

Figure 3. Municipalities located within Pantanal and major surrounding towns
Source: Silva and Abdon (1998)

When gold mining declined, cattle breeding was initiated in the region. European cattle were introduced to the large areas covered by native pastures in an extensive system in which no technology has been used for a long time. Initially only mineral salt was used, but later new technologies such as reproduction season, vaccination, intestinal parasites control, and cultivated grass were introduced in small areas while keeping the biodiversity and production system as natural as possible. As a result, the Pantanal is the best-conserved ecosystem complex in the country in terms of biodiversity and ecosystem functioning.

The first cattle were European, but they were later replaced by the zebu Nelore from India. The use of fire was and is common. Fire eliminates dry areas of hard grasses and improves pasture quality with re-sprouting. A few cowboys looked after hundreds of heads, and lived in very simple huts built in higher areas. The cowboys would join the cattle in July for counting and separating those animals to be sold. This operation is still performed twice a year, between

May and June and in November. Each ranch cultivated a small piece of land where cassava, banana, sugar cane and some vegetables were grown.

The landowner did not live on the ranch, but visited once or twice a year to check and monitor annual production. This situation has changed; a ranch today needs to be managed as a corporation and some of the ranchers live in the area or now visit very often. The ranches are generally at distant, isolated locations and long walks are necessary to take the cattle to market.

Beef cattle breeding has been the main economic activity of the Pantanal and continues to be. The herd figures fluctuate depending on climatic conditions, flood level, and market prices. The data indicate a herd in the past of over four million head; nowadays the herd is estimated at three million.

This system has contributed to the conservation of Pantanal biodiversity. Cattle can live together with wild animals without causing any apparent serious ecological problem. There is no competition for food because the Pantanal has no natural populations of large herbivores and forage availability is higher than the animal consumption, which occurs mainly in the rainy season and in lower areas after floods. It seems to be a very good combination and it is possible to observe strong populations of herbivorous, even carnivorous, mammals living together. Of course the environmental conditions and the lack of infrastructure such as roads, electric power, and communication have been favourable to such a development. But undoubtedly the life style and philosophy of these people contribute greatly to this situation.

Some other economic activities have been attempted. The region was for some time the second major sugar cane producer in the country with nine plants working along the Cuiaba and Paraguay Rivers. Dry and salted meat was traded and caiman, jaguar, and capybara skins, among others, were exported, despite being illegal.

Sport fishing and tourism have increased over the last 15 years and are the second leading economic activities. Eco-tourism and other tourist activities (bird watching, tracking, scientific tourism, catch and release type fishing, etc.) will perhaps increase and eventually overtake beef cattle breeding in economic importance.

There is a great potential in the higher areas around the Pantanal for mining iron, manganese, phosphate, and limestone. Mining of iron and manganese in particular is increasing, with melting plants set up in areas with adequate electrical power.

Threats to Biodiversity

No serious environmental impacts are generated inside the Pantanal plain, but agricultural activities and cultivated pastures on the sandy soils of the plateau have caused tremendous disaster in the plain, resulting in the siltation and sedimentation of some tributaries of the Paraguay River. The worst example is the Taquari River (Figure 4). This process occurred naturally for thousands of

years but actually it is now occurring more rapidly, causing the lifting of the riverbed, the collapse of the riverbanks, and flooding of large areas during most of the year. That has forced farmers and small holders to move out, abandoning their no-longer-productive lands. This is, in the author's opinion, the most serious and complicated ecological problem in the Pantanal. There are other less significant problems such as the contamination of water bodies by mercury resulting from gold mining operations, and the consequent contamination of microorganisms, fishes, birds, and animals that feed on aquatic organisms. There are also threats of aquatic contamination by agrochemicals. All of these problems originated outside the plain.

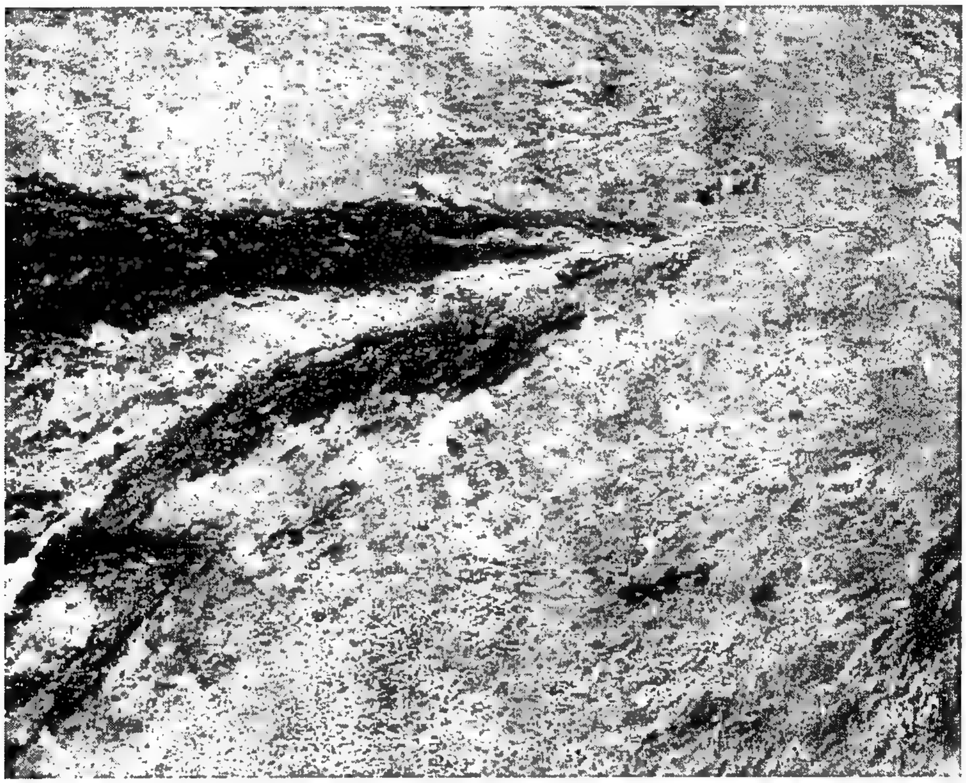

Figure 4. Taquari River flooded area

Within the plain some areas covered by forest or dense arboreal vegetation, called "cordilheiras," have been cleared to cultivate pastures. Those areas represent about 3.9 percent of the Brazilian Pantanal. The increase of agricultural activities in the planalto or highlands surrounding the plain, the implementation of projects like Paraguay-Parana Waterway, or Hidrovia, the Bolivia-Brazil gas pipeline already constructed, roads, dikes, and tourist infrastructure also represent risks for biodiversity conservation if actions to reduce, mitigate, or avoid impacts are not implemented.

Newcomers are introducing new technologies, including land preparation and sowing Brachiaria grass between the tree islands, and deforestation of shrubby and arboreal vegetation in a way completely different from the pantaneiro production system. These people are breaking the traditional living style of the region, causing risks to the environment.

Development Plans

The government has carried out many studies and plans for development of the Pantanal (Table 3), starting with the hydrologic studies conducted in 1970 by DNOS (National Department for Works and Sanitation) that resulted in a profile or a hydrologic model of water behaviour (SUDECO 1979).

Table 3
Studies and Development Plans

Year	Responsible	Action
1970	DNOS	Hydrologic model
1971	Prodoeste	Economic frontiers
	Porto	Subsidies for development program
1973	Silvestre	Potentialities of Pantanal
1974	Geipot	Collector road system
	Prodepan	Transport, sanitation, electricity
1977	EDIBAP	Integrated development
1994	PCBAP	Diagnostic and ecological zoning
2000	IDB	Pantanal Program

In 1971, the PRODOESTE (Program for the Development of Centre-West) introduced new economic frontiers to the whole region (SUDECO 1979). Another study was conducted by Porto (1971) on "Subsidies for Pantanal development program" where he considered economic and social stagnation as the main hindrance to the development of the Pantanal. The origin of this problem would be the lack of public and private investments and extractive activity. Porto identified the potential of the region and provided guidelines for a development program.

A study entitled "The Characteristics and Potentialities of the Matogrossense Pantanal" was published in 1973 presenting a diagnostic of the region considering the most relevant aspects – delimitation, abiotic and biotic natural resources, infrastructure, and position of productive sectors. Recommendations also have been provided to help guide development of the region. These recommendations included actions for the improvement of the transport system through the construction of nine roads, fluvial transportation and railways. Electricity generation has also been considered, as well as agriculture and husbandry, industry, public health, and water supply (Silvestre et al. 1973) (Figure 5).

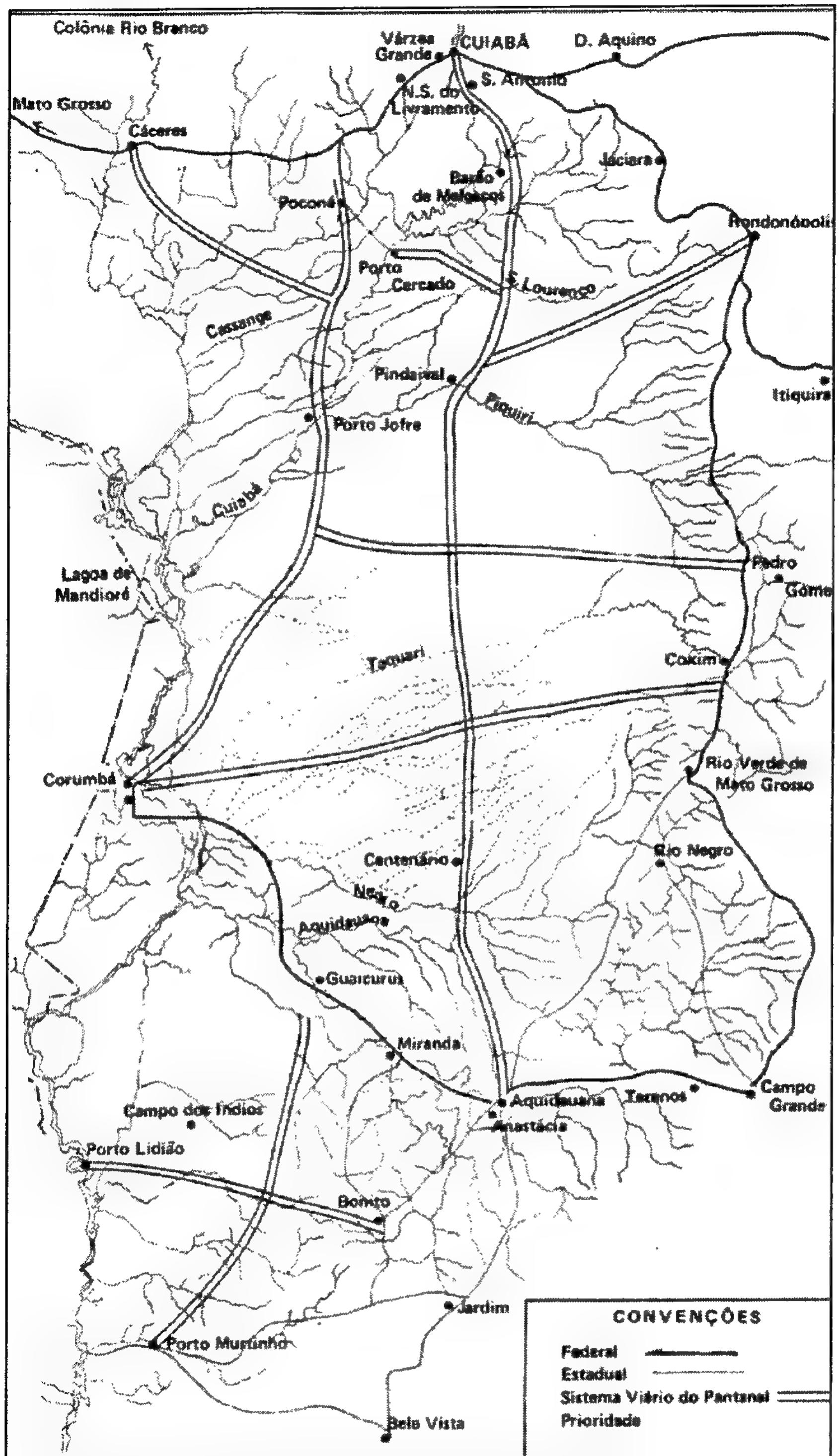

Figure 5. Road infrastructure plan for the Pantanal (Source: Silvestre et al. (1973))

In 1974 the PRODEPAN (Special Program for the Development of Pantanal) was created. Its objective was to integrate the Pantanal physically and economically with other parts of the country and exploit its full potential.

Following the recommendations of Silvestre et al. (1973), this program concentrated its actions from 1974 to 1976 on transport, sanitation (water supply), generation and transmission of electricity, agriculture research and technical assistance as well as industry mainly for the regional products, beef and mining ores. This was perhaps the most important development program implemented to date in this region, applying Cr$650 million (Brazilian currency at time = US$338 million).

These actions have resulted in significant achievements, mainly opening of roads, improvement of railways and waterways, opening of drainage channels, construction of electricity transmission lines and the creation of an agricultural research unit, EMBRAPA-CPAP.

In 1977 a cooperative agreement between the Brazilian government and UNDP (United Nations Development Program) was established with the support of OAS (Organization of American States) to implement the EDIBAP (Study for the Integrated Development of Upper Paraguay Basin). It was a very ambitious program (SUDECO 1979).

The PCBAP (Upper Paraguay River Basin Conservation Plan) is the most important study carried out recently in the Pantanal region. The methodology utilized for the development of this plan (Volume I) involved the Integrated Diagnostic, the Environmental Zoning and the Utilisation and Occupation Prognostic based on environmental conservation, rehabilitation, and sustainable development (MMA 1997a, 1997b).

A new program for the sustainable development of the Pantanal, the Pantanal Program, is under implementation by the federal government with the cooperation of the two states – Mato Grosso (MT) and Motto Grosso do Sul (MS). This program includes five components: watershed management, urban development, establishment and rehabilitation of parkways, promotion of sustainable development activities, and institutional strengthening (Inter-American Development Bank 2000).

Sustainable Development

The first discussions and studies for the development of Pantanal considered only the economic and social development, with a primary focus on economically integrating this region with other parts of the country. The dominant ideas were construction of roads, dikes, polder, electricity transmission lines, etc. Nowadays it is very clear that environmental issues are critical and must be considered in any project.

The globalization of the economy and the increasing preoccupation with environmental conservation as it affects the Pantanal economy present new demands for research in this region. The great challenge is to achieve sustainable development so the research must generate or adapt knowledge and technology to increase productivity and incomes, while conserving habitats, flora and fauna, and ecological functions.

Many institutions have conducted research on biology, ecology, floristic and faunistic surveys, mapping of natural resources, soil classification, geology, geomorphology, hydrology, limnology, climatology, and so on. Substantial results have been produced despite being dispersed. However it is also necessary to work on understanding the pantaneiro culture and traditions.

Many people think that sustainable development is impossible. Perhaps it is a bit utopian, but utopia (any idealized place, state, or situation of perfection) can be achieved depending on one's determination. The Pantanal offers many alternatives. There is a great potential for tourism, for sustainable management of floral and faunal resources, especially fish resources. There is also a potential to increase the productivity of the cattle production system and to get special prices for meat produced in this region because of its low cholesterol content. There are several ways of improving living conditions. Thousands of caiman and capybara skins could be sold if the laws and the international market were not so restrictive. That would mean thousands of American dollars and creation of hundreds of jobs. Most important is that there is technology for the sustainable management of those populations.

Sustainable development can be reached but it is necessary that everyone understand its philosophy. Basic knowledge and technology must be generated to implement this idea in all branches of economic activities.

Conclusion

During the last 30 years, the Brazilian government has implemented studies and development projects to economically integrate the Pantanal with the rest of the country. But, in the last 10 years those studies and projects have increasingly included the idea of conservation and sustainable development.

Pantaneiros have conserved the Pantanal for more than two centuries and they wish to maintain the beauty, biodiversity, and exuberance of this region as it has been maintained so far. Urgent and practical actions must be implemented in the Planalto surrounding the Pantanal to control erosion processes and, in consequence, siltation and sedimentation of Pantanal aquatic systems. Environmental impact studies must be carried out prior to implementing any project. Ecological tourism and other types of tourism must be improved with professionally trained people.

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About the Author

Mario Dantas, PhD, biologist and plant ecologist, worked for 20 years in the Brazilian Amazon and for 10 years in the Pantanal. He was a scientist with EMBRAPA for 25 years and served as director of the Pantanal Centre of EMBRAPA. He is now retired, working as university lecturer and consultant on Pantanal affairs.

4 Conflicts and Contradictions on the Occupation of the Pantanal Space (*Conflitos e Contradições na Ocupação do Espaço Pantaneiro*)

Antônio Augusto Rossotto Ioris
Department of Geography and Environment, University of Aberdeen, Scotland
Postal Address: SEPA, Erskine Court, Castle Business Park, Stirling, FK9 4TR, Scotland, UK
e-mail: *geo435@abdn.ac.uk*; *aioris@hotmail.com*; *antonio.ioris@mma.gov.br*

Abstract (*Resumo*)

Traditional productive activities in the Pantanal have been under growing pressure to compete with capital-intensive agriculture. National and international market forces, along with political and geopolitical disputes, intensify that process. The intensive exploitation of natural resources has affected the use of space in the entire region, transforming not only rural and urban landscapes, but also human relations. It has produced environmental consequences that compromise the long-term conservation of the Pantanal. Such questions pose increasing demands on the response capacity of local and national governments. The environmental management of the Pantanal depends not only on robust knowledge and institutional strengthening, but on conflict resolution, which is closely related to the revitalization of representative democracy.

A exploração tradicional do Pantanal tem enfrentado crescentes dificuldades para competir com novas atividades agrícolas baseadas no uso intensivo de capital. Tal processo de intensificação é resultado de forças de mercado nacionais e internacionais, concomitantemente com disputas políticas e geopolíticas. A exploração intensiva dos recursos naturais tem afetado o uso do espaço, transformando não apenas a paisagem urbana e rural, mas também as relações humanas. As conseqüências ambientais decorrentes comprometem a

conservação de longo prazo do Pantanal e desafiam a capacidade dos governos nacionais e estaduais. A gestão ambiental do Pantanal depende não somente de avanços científicos e institucionais, mas a solução de conflitos é também diretamente relacionada à revitalização da democracia representativa.

Key Words

Pantanal, spatial dynamics, socio-environmental conflicts (*Pantanal, dinâmicas espaciais, conflitos sócio-ambientais*)

Introduction

The Pantanal is famous for its abundant biodiversity, intricate ecosystem functions, and picturesque rural culture. It is also a region with fascinating historical traditions, inasmuch as it was situated on the edge between the Portuguese and the Spanish colonial enterprises since the early stages of Iberian expansion. The Pantanal is currently recognized as one of the most important tropical wetlands in the world, but is also one of the most threatened. Because of that, the conservation of the Pantanal has drawn growing international attention and has become the object of passionate local debates. The complexity and importance of this major transboundary wetland have placed serious demands upon the institutions responsible for the regulation and conservation of natural resources. The present situation is one of multifaceted, contradictory interests in the Pantanal and its surrounding areas. In the majority of cases, the institutional response to such challenging demands has been primarily reactive and unevenly successful.

A Complex Social and Natural Landscape

The Pantanal is an extensive floodplain that occupies the (relative) geographical depression in the center of the Upper Paraguay River Basin (UPRB). As reported by Consórcio Inter-municipal para o Desen Volvi mento Integrado das Bacias dos Rios Miranda e Apa (CIDEMA) (2001, quoting a study of Luiz Englert Foundation), the UPRB encompasses 595,230 km^2, which represents approximately 60 percent of the Paraguay River Basin and 16 percent of the Plata River Basin. The UPRB is shared by Brazil (363,460 km^2), Bolivia (121,460 km^2) and Paraguay (110,410 km^2). According to PCBAP (1997), the area of the UPRB in the Brazilian territory is 361,666 km^2 and the Pantanal extends for 138,183 km^2. However, Adámoli (2000) argues that the floodplain area alone represents a total of 417,000 km^2 with a surface of 138,000 km^2 situated in Brazil. Those spatial figures are a matter of constant dispute, because the boundary of this unique river system is not clearly defined, but confounds itself with the Chaco and the Amazon Basin on its western limits.

The primary natural feature of the Pantanal is the seasonal flooding regime, which determines both geomorphology and biodiversity. The natural pulse of inundation and desiccation has specific patterns in each section of the Pantanal, which creates a mosaic of sub-regions with individual ecological characteristics.

At the same time, there is a distinct interannual variability with successive cycles of dry and wet years (Adámoli 1986, Tucci et al. 1999). In Brazil, there are 175 rivers entering the Pantanal floodplain, which deliver water, nutrients, and sediments. The mean river flow is 1,770 cumecs at the most downstream reaches of the Paraguay River in the Brazilian territory (i.e., at the confluence with the Apa River). The water drained by the river network in the Pantanal represents only 8 percent of total rainfall, since 92 percent evapotranspirates (Salati et al. 1999). That demonstrates the importance of soil-water interaction for the water balance and the conservation of the Pantanal. In terms of quantification of benefits obtained from natural services, Seidl and Moraes (2000) calculate that water supply and ecological disturbance regulation represent two thirds of the value of ecosystem services in the Pantanal (followed by waste treatment, cultural value, and water regulation services).

In the last few decades, the Brazilian (eastern) segment of the Pantanal has been reasonably monitored and studied. A significant scientific literature on the Pantanal is already available, mainly published in Portuguese. Hamilton (2002a) describes the uniqueness of the Pantanal environment, describing the principal hydrological processes that determine the ecological structure and function of the floodplains. The hydrological characteristics of the seasonal flood pulse include frequency (generally once per year), depth of inundation (ranges from <10 cm to 2 m or more) and the duration of the inundation (usually continuous over 1-2 months or longer). Hamilton (2002a) adds that the high species diversity and biological productivity of the Pantanal is explained by this seasonal inundation, which maintains a spatially and temporally variable environment with both aquatic and terrestrial characteristics. "Floodplains such as the Pantanal seem to be in a constant state of disturbance, and many of the plant and animal species must be resilient to flourish in such an environment" (Hamilton 2002a).

Scientific research has shown that the most severe environmental problems in the Pantanal result from alteration in hydrology and use of soil. That is basically the consequence of agricultural production, but is also related to the construction of roads, dikes, and dams (for hydropower generation or flood control) and disorganized urbanization (without proper infrastructure). Furthermore, Collinschonn et al. (2001) suggest that climate change could be a new matter of concern in the Paraguay River basin, since not all recent changes in runoff can be attributed to the alteration of land use. There are still other activities that have impacted the ecological equilibrium of the Pantanal, such as unregulated sport fishing (deficient control of captured quantities). In addition, Hylander et al. (2000) detected concentrations of mercury above thresholds in analysis of fish tissue as a consequence of artisanal gold-mining activities. The economic and social processes behind those environmental questions are examined herein.

Spatial and Socioeconomic Transformations

There is historical evidence of Iberian presence in the Pantanal since the early 16th Century. The first Portuguese military fortifications in the Pantanal, in 1775, were sites of outstanding strategic importance for the control of the Paraguay River. At that time, river navigation was the basic means of transport,

connecting Corumbá (in the heart of the Pantanal) with Buenos Aires and Rio de Janeiro. The effective colonial occupation of the region occurred in the late 18th Century, with cattle ranching as the main economic activity. Since that period, the Brazilian Pantanal has been a supplier of meat, leather, calves, and steers to the main national economic centers. The Pantanal has, therefore, served to secure the national borders on the extreme west of the country and, more importantly, has played its role in the Brazilian economy.

Since the first stages, production activities taking place in the Pantanal were intimately connected with the capitalist expansion in Brazil, but happened under an uneven power relation with the stronger political and economic centers. In other words, the region was a satellite of the national metropolises, in a process of subordination and dependency described by Frank (1967) for other parts of Brazil. According to this interpretation, to the same extent that Brazil (and South America as a whole) was a satellite of the industrial countries of the world, peripheral regions, like the Pantanal, were satellites of the national dominating regions. The economic function of the "satellite Pantanal" was to transform its natural pastures into food and raw material.

The Pantanal is a region characterized by huge farms with very low population density. In the past, during the rainy season (approximately half of the year) transport and communication virtually ceased. Local farms had to develop a high proportion of self-sufficiency in terms of resources, technology, and equipment. Currently, cattle ranching is still the fundamental economic activity in the floodplain and, to a great extent, it resembles the previous epochs. The unique Pantanal geography does not serve as mere substratum for social interactions, but it is an integral part of the process of production. It creates a vivid hybrid between society and nature in the river basin, what Swyngedouw (1999) defines as the creation of "socionature." In other words, the intense human intervention (or interaction) in the water cycle is responsible for the hybrid character of the landscape, both social and natural.

The ecological impact of traditional cattle production is relatively low, since it is an extensive activity that adapted itself to the local environment. However, the cattle industry began to change in the last decades of the 20th Century. Due to the modest rates of capital productivity in the Pantanal floodplain, production techniques started to intensify and incorporate more and more external inputs (i.e. machinery, artificial pastures, wire fences, veterinary medicines, mineral supplements, etc). Seidl et al. (2001) point out that about 95 percent of the Pantanal lands are privately owned and about 80 percent are used as extensively managed cattle ranches. Nevertheless, as a result of those recent economic pressures, the amount of agricultural property is increasing, cattle density and numbers are decreasing, the proportion of land in cultivated pastures is decreasing, and the amount of land in natural pastures is also decreasing. The overall spatial and economic result is that land and animal wealth, which had always been highly concentrated, are in a process of further concentration.

Despite the fact that the intensification of floodplain farming has created negative environmental externalities, most of the threats to the Pantanal ecology come from spatial changes in the surrounding uplands (areas higher than 200 m in altitude). The main pressures in the uplands are the mushrooming urbanization

process (with neither land use planning nor waste and sewage treatment) and the constant expansion of intensive agriculture (crop and cattle production, as well as ethanol produced from sugar cane). The conversion of the upland soils surrounding the Pantanal (Oxisols for crops and Podzols for pastures) has been highly problematic, because most of the agronomic techniques employed were not adapted to local tropical conditions (i.e. high temperature and erosive rainfall). Agriculture has been responsible for deforestation, biodiversity loss, water pollution and, especially, soil erosion.

Conversion of the uplands into plantation farms started in the 1960s, with the arrival of a great number of migrants from the southern states of Brazil. Market forces alone did not stimulate this demographic movement; it was also boosted by aggressive, authoritarian national development plans. The so-called "agriculture frontier" was galvanized by heavy subsidies and governmental investments in commodity storage and distribution. Official agencies were responsible for providing rural credit, conducting agricultural research and disseminating technologies through rural extension. At the same time, transport and communication infrastructure had to improve to allow the connection of the region with the rest of Brazil. This expansionist process continues today, but since 1990 under a more market-oriented approach (i.e. with fewer subsidies, private sources of credit, more integrated production, professional farm management, etc). The cattle industry is presently facing a period of "modernization" in Brazil as a whole (similar to what happened 30 years ago with the crop industry) and the country is now a world leader in meat production.

At the beginning of the 21st century, transformations in production activities have raised fierce controversy and have demanded scientific responses that are beyond existing knowledge. There are also new players involved in the environmental disputes, such as scientists, environmentalists, landless groups, indigenous peoples, energy suppliers (natural gas and hydropower), and navigation companies. The most evident contentions are the result of campaigns of local and international environmentalist groups against non-adapted farming. However, hydropower generation, and road and navigation expansion have also come under fire. Navigation, in particular, is strongly supported by grain producers that intend to use the Paraguay and the Plata Rivers to reduce exportation costs. However, the likely threats posed by a larger navigation network are changes in water velocity, discharge, surface elevation, and sediment load. On the geopolitical scale, the Bolivian government has expressed its intention to construct a transcontinental motorway crossing the middle of the Pantanal to offer Brazilian exporters an easier access to Pacific ports. A transcontinental pipeline was recently built, which crosses the Pantanal to convey gas from Bolivian reserves to satisfy industrial and urban demands in Brazil. There is also a plan to attract foreign investment to install an industrial complex in the Bolivian Pantanal, making use of its abundant natural gas (this plan was presented by the Bolivian ambassador in a meeting with the author in 2001). It serves to demonstrate why the Pantanal is now on the top of the agenda of the international relations among Mercosur ("Common Market of the Southern Cone") country members.

The last few years have been a period of economic and political reorganization regarding the use and conservation of the Pantanal. The overall

consequence for the Pantanal environment is that the traditional, low-impact production industry of the Pantanal is increasingly in direct competition with capital-intensive activities in the floodplain and the surrounding uplands. That has affected the entire region, transforming the rural and urban landscapes. The main shift has been the transference of economic leadership from the floodplain to upland areas, which has concentrated benefits in the hands of "input-intensive" farmers and agribusiness corporations. While in the 18th and 19th centuries the traditional Pantanal oligarchy was the leading political group in the central region of Brazil, these same farmers are now politically and economically marginalized. For instance, there is restricted political representation of Pantanal farmers in the state and federal governments and in the respective parliaments. They have limited input in budgeting and planning. For instance, their demands for more roads and rural electricity in the floodplain are systematically forgotten. Moreover, such demands are strongly opposed by environmentalists and many scientists, serving to further isolate the Pantanal farmers.

The creation of new spaces and social relations follows an uneven pattern of development in the Pantanal. There are groups and places benefiting from the recent transformations, while others gradually lose importance. There are emerging disputes between urban and rural, old and new, landlords and employees, institutions and citizens, environment and society, and so forth. Such phenomena are not exclusive to the Pantanal, but have been recurrent in all recent agricultural expansion in Brazil (as in other parts of the same Central Region, in the Amazon Basin, and in irrigated areas in the Northeast of the country). For the majority of the population in the cities and in the countryside, the recent modernization process has offered scarce improvements in living standards and in terms of political opportunities. It has ultimately been a transition from one elitist economic system, dominated by large Pantanal farmers, to another elitist system, now controlled by urban interests and plantation farmers.

Nevertheless, the social and environmental reality of the Pantanal is too complex for any simplistic, schematic explanation. The transformations taking place in the Pantanal and its surrounding areas are constantly challenging established patterns of behavior. The social and political consequences of those transformations provoke unpredicted reactions and foster new alliances or novel disputes. That is the reason why the management of the Pantanal environment calls for an improvement in the capacity of representative democracy to negotiate interests and mediate conflicts. If the environmental problems are provoked by transformations that are externally and internally driven, the solutions need to consider reactions both within the Pantanal region and in connection with broader environmental reactions operating at the national and international scales.

Institutional Responses and Failures

International cooperation is critical to the conservation of the Plata and Paraguay Basins. The challenge is to translate aspirations of cooperation into effective and lasting responses. Going beyond diplomacy, the underlying problem is how to be proactive rather than reactive when considering

environmental questions. A plan of measures for the management of the Plata Basin was first agreed upon in 1933 at a Conference in Montevideo, but resulted in no practical achievements. In 1969, the Plata Treaty was signed in Brasília, with ambitious aims, but, again, with frustrating outcomes so far. More recently, though, there has been a new attempt to integrate national environmental policies. Elhance (1999) identifies some progress in the relationship between the countries that form the Plata Basin (Argentina, Bolivia, Brazil, Paraguay, and Uruguay). This author sees a shift from original "unilateralism" to "bilateralism" (in the 1970s) and, at present, a convergence towards "multilateralism."

It must be noted that the institutional strengthening for the conservation of the Pantanal is not restricted to improvements in governmental agencies alone. It requires changes in patterns of relation between social groups and between society and nature. The institutional arrangement is the combination of legislation and regulation, policies and guidelines, administrative structures, economic and financial arrangements, political structures and processes, historical and traditional customs and values, and key participants or actors (Mitchell and Pigram 1989). The institutional framework sets the ground rules for resource use and facilitates the achievement of economic and social goals. In contrast, ill-conceived institutions establish impediments to efficient resource use and, thus, significant resources must be expended by individuals to compensate for their obsolete or poor design (Livingston 1995).

Moving back to the national context, a series of development and conservation programs have been promoted in Brazil since the 1970s (see Ioris (2001)). Landmark initiatives were:

- CIDEPAN (1971) – consortium of municipalities.
- PRODEPAN (1974/78) – development plan that included water regularization, infrastructure and production incentives.
- EDIBAP (1978/81) – geographic study and development plan.

The modest outcomes of the previous plans prompted a new "generation" of initiatives under the direct management of the Ministry of the Environment. The most relevant initiatives are:

- PCBAP (1994/97) – comprehensive study and plan of conservation; the final publication is now the "encyclopaedia of the Pantanal."
- "GEF Project - Integrated Management Program for the Pantanal and the UPRB" (1999 onwards) – local and regional projects related to scientific research and environmental management.
- "Programme for the Sustainable Development of the Pantanal" (2001 onwards) – seven broad portfolios of investments and associated management strategies.

It is important to observe that Brazil is a federal country and the Pantanal is shared by two of the 27 Brazilian states (respectively, Mato Grosso and Mato

Grosso do Sul). The states have complementary legal responsibilities to regulate and manage the use of natural resources. That is carried out by specific branches of the governmental structure (i.e. state secretariats of the environment, which are responsible for the two institutes that deal with environmental conservation – FEMA and IMAP). At the local level, municipalities can also institute environmental agencies with some additional responsibilities. According to the federal Constitution, environmental policies must be coordinated with and supported by the national government. In order to do so, the Ministry of the Environment has two main operational agencies (i.e. IBAMA for conservation units, fisheries, wildlife and natural resources, and ANA for water resources). Those three levels of government (federal, state, and municipal) have independent budgeting systems, which have to be independently approved by the respective parliaments.

Despite the existence of a formal institutional arrangement, the environmental management of the Pantanal is still performed by agencies with shared and fragmented responsibilities, either from one level of government to another (local, state, federal) or among agencies at the same level of government (water, agriculture, forestry, etc.). There is also a chronic difficulty in integrating the actions of Mato Grosso and Mato Grosso do Sul, as well as between both states and the federal government. The environmental legislation sometimes contributes to confusion on the specific responsibilities and liabilities of each organization. More serious is the problem of sporadic political support to the conservation of the Pantanal, which inevitably results in discontinuity of efforts and waste of resources. An associated question is the lack of transparency in the decision-making process, the passive involvement of most interested parties, and the frequently difficult dialogue with the most critical stakeholder groups.

As a paradigmatic example of the institutional failures, the two ongoing programs mentioned above (i.e. GEF and Pantanal Program) have been seriously affected by difficulties that are beyond the control of their direct managers, such as macroeconomic constraints and cabinet reshuffles after general elections. Despite years of preparation and hundreds of meetings, the present situation is one of organizations with unskilled and unmotivated staff, struggling with limited financial resources and having to deal with too many uncertainties. There are major obstacles to translate the scientific results produced by research centers and universities into proper management. On the other hand, inadequate program management is also responsible for creating a great proportion of the questions affecting those programs. It is not rare to see parochial interests interfering with decision making and wasting time or resources. Managers and agencies frequently promote strategies or techniques that are not appropriate to the Pantanal's natural and social context. Inept consultants and negligent politicians often aggravate the problem, as analyzed by Ioris (2002).

The Worst Case: Tragedies and Prospects for the Taquari

The environmental degradation of the Taquari River, one of the larger rivers in the Pantanal, is probably the most dramatic example of a combination of

policy mistakes, reckless response, and obstacles to effective dialogue. Degradation of the Taquari is the result of ill-conceived human intervention (deforestation in the Upper Taquari) creating severe impacts on an unstable river system, as explained in detail elsewhere (Souza et al., Dantas, and Jongman, this volume). In a nutshell, what happened was a chain of disruptive geomorphological events: changes in land use upstream modified the water and sediment regimes, which affected flood patterns and land use downstream. The consequence has been longer periods of flooding covering more extensive areas. The progressive deforestation that took place in the uplands of the Taquari catchment since the 1960s, particularly for soybean and cattle production, resulted in higher sediment rates and higher mean river flow, which is related to the lower rates of evapotranspiration of pastures in comparison with the original savannah (Collinschonn and Tucci 2002). Due to higher flows and accelerated sedimentation, the (very low) riverbanks of the Taquari began to collapse. That has led to "riverbank cuts" (levee openings) resulting in the diversion of water flow to the adjacent fields. For Hamilton (2002b), levee openings in the Taquari are a natural process (since this is a juvenile floodplain river, which is still setting its geomorphological destiny), but the high rates of sedimentation have augmented the natural instability.

This environmental disruption has provoked the greatest social and environmental "tragedies" of the Pantanal. The most notorious dilemma has been the fate of an entire rural community of small farmers and squatters that lived in the lower section of the Taquari catchment since the early 20th century (attracted to this area by the pioneer of the expansion to the west of Brazil, Marshal Rondon). Because of the persistent floods that occur in the area, the community had to leave their land and livelihoods. These are typical "environmental refugees," who now live in shantytowns around Corumbá and Campo Grande (the main cities in Mato Grosso do Sul). These "refugees" have tried to organize themselves to claim compensation for their property losses, but neither the federal authorities nor the state governments have been able to find a satisfactory and reasonable solution to this problem. While peasants and squatters are the most affected people, since they lost their means of subsistence, farmers along the right margin of the river have also faced reductions in the land available for cattle grazing.

Environmental degradation of the Taquari occurred over a few decades. Trying to restore the river is now a mammoth task that will certainly last for generations. Most of the environmental impacts are certainly irreversible. This is a "tragedy of the commons" (cf. Hardin (1968)) that engenders a series of related "tragedies." That is to say that the Taquari case is not only an environmental disaster, but also a political and institutional quandary. Those "tragedies" are consequences of successive misunderstandings about the natural dynamics of the Taquari, which gave rise to totally inappropriate exploitation of the river basin resources. An extreme example of such misconceptions about the local environment was a proposal put forward by PRODEPLAN in 1974 (fortunately not implemented), which aimed to divert water from the Taquari to stimulate agricultural uses in a 600,000-ha area (Abreu 2000), without providing adequate drainage. This demonstrates the distance between decision making and the local socio-environmental reality.

A very modest, but relatively successful experience that deserves to be reported here was the recent attempt to reach consensus on restoration of the Taquari River. It was part of the activities of the Pantanal Program (mentioned above) and was a deliberate strategy to deal with the complexity and uncertainty associated with the Taquari degradation. After careful consideration, a steering group (so-called "Technical Committee of the Taquari") was formed in December 2001 with representatives from several invited organizations. Following suggestions by those initial members, additional organizations were later invited to join the steering group. The total membership comprises 20 representatives of municipal, state, and federal agencies, NGOs, universities, research centers, and professional bodies (farmers, fishermen and agronomists). A series of discussions and workshops was promoted to evaluate a long list of restoration suggestions, many of which were contradictory. Ad hoc working groups were also formed to examine specific technical questions.

Contrary to the expectations of many, the meetings and activities of the steering group were extremely productive. Controversial topics were enthusiastically debated, in what was a unique chance for the exchange of ideas between scientists, farmers, environmentalists, and civil servants. People demonstrated their true commitment to finding solutions to the Taquari problems, without negative criticism or unreasonable demands. The uncertainties and concerns of each sector were honestly presented and, after one side listened to the other, it was possible to reach a significant level of compromise. The results of the Taquari steering group corroborate the statements of Hodge and McNally (2000) that collective action is important for wetland restoration, both because of the physical interactions among landholders and because of the cost savings and enhanced environmental benefits that can be achieved at a larger scale. Policy needs to be geared towards facilitating cooperation if environmental remedies are to be effective in enabling wetland restoration.

The outcomes of this experience were the result of legitimate, transparent negotiation between interested parties. Particularly important was the fact that it was one of the first occasions in which groups from the upper and lower Taquari basin were able to constructively debate the degradation and restoration of the river. Unfortunately, despite such an encouraging initial experience, the implementation of the Pantanal Program has been delayed for political and macroeconomic reasons since 2002. It is difficult to predict what it going to happen to the river restoration in the next few years, but it is important to recognize that the consensus reached at the Taquari committee was a valuable starting point.

Conclusion

The ecological condition of the Pantanal has been affected by transformations related to natural resources exploitation in both the floodplain and the uplands. The human interference in the Pantanal landscape has produced new physical and social constructs. It is a multidimensional interaction that exacerbates conflicts and creates new disputes. The main conflicts are those between the conservation and the exploitation of natural resources, which are

related to the opposition between traditional, "stable" farming and mechanized, "risky" agribusiness. Those socio-natural controversies have provoked a range of contradictory results, with uneven socio-economic development and progressive environmental disruption.

This text is a brief account of an intricate "chess played on the Pantanal board," with some "kings" and "rooks," among a large population of "pawns." Local stakeholders are struggling to define a consistent agenda that suits their interests, but sometimes they seem confused by the very dynamic political and economic movements. The complex environmental disputes have posed growing demands on the response capacity of state and federal governments. In most cases, the responses have been uncoordinated, deficient, and tardy. However, more than scientific research, the solution to such dilemmas is ultimately dependent on institutional strengthening and on the renewal of representative democracy.

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About the Author

Antônio A. R Ioris was the General Water Resources Manager of the "Programme for the Sustainable Development of the Pantanal" (the so-called *Programa Pantanal*), Ministry of the Environment, Brasília, Brazil, in the years 2001 and 2002.

More information about the program can be found on the site: *www.mma.gov.br/port/sqa/index.cfm*

The central management office can be contacted at:
Programa Pantanal (MMA)
SHIN – CA 05, Conjunto J
Bloco B, Salas 210-215
Brasília, DF, 71503-505, Brazil
Phone/Fax: +55 61 468 6575
programa.pantanal@mma.gov.br

5 An Aproach to the Sustainable Use of the Natural Resources of the Pantanal, Upper Paraguay River Basin, Brazil (*Uma Discussão sobre o Uso Sustentável dos Recursos Naturais do Pantanal, Bacia do Alto Paraguai, Brasil*)

Emiko Kawakami de Resende
EMBRAPA-CPAP, Rua 21 de Setembro, 1880. 79320-900, Corumbá, Mato Grosso d Sul
e-mail: *emiko@cpap.embrapa.br*

Abstract (*Resumo*)

This article gives a general description of the Pantanal, one of the largest freshwater wetlands in the world and discusses the flood pulse as a major ecological process contributing to the richness, diversity, and abundance of life in this kind of environment.

O artigo traz uma descrição geral do Pantanal, o qual é uma das mais extensas áreas úmidas de água doce do mundo, e descreve o pulso de inundação como um dos principais processos que explicam a riqueza, diversidade e abundância de vida em ambientes com tais características.

Keywords

Pantanal, flood pulse concept, richness, abundance of life (*Pantanal, conceito de pulso de inundação, riqueza biológica, abundância de formas de vida*)

Introduction

The Pantanal, an immense alluvial plain within the Upper Paraguay River Basin, is located in central-western Brazil, eastern Bolivia, and northeastern Paraguay (Figure 1). The whole area of the Upper Paraguay Basin is 496,000 km^2, of which 396,800 km^2 lay within Brazil; in the states of Mato Grosso and Mato Grosso do Sul. Altitudes range from 80-150 m on the plains, to over 250 m on the highlands, with some isolated peaks over 1,000 m, southeast of Corumba (Wade et al. 1993). Principal rivers in the basin include the Paraguay itself, Cuiabá, São Lourenço, Itiquira, Taquari, Aquidauana, Negro, and Miranda, all originating in the highlands. So, an understanding of the ecology and management of the Pantanal requires consideration of the basin as a whole, both plain and highlands.

Total yearly rainfall in the basin is approximately 1100-1500 mm, 80 percent of which falls from November to March (Alfonsi and Camargo 1986). Beginning with November rains in the highlands, the Pantanal is inundated slowly, from north to south along the Paraguay River and from east to west along the main tributaries, including the São Lourenço and Taquari Rivers, changing it into a vast, shallow inland sea, with spots of higher areas that do not flood. Flooding may last 3 to 9 months, depending on local elevation. Maximum water levels normally occur during January and February in the northern and eastern reaches of the Paraguay River and its tributaries and during May and June in the southern areas. After peak floods, the system dries slowly through river drainage, evaporation, and evapotranspiration. The landscape changes to a huge savannah, with open grasslands, isolated strings and pockets of cerrado vegetation and many shallow water bodies. This results in a large number of trapped fish, attracting numerous piscivorous birds and caiman.

The Pantanal ecosystem is regulated by an annual cycle of flooding and drought, including a multi-year pattern involving occasional greater fluctuations, or pulses, in the cycle (Figure 2). Hydrologically, the Pantanal functions as a large sponge that absorbs and then slowly releases the flow of water coming from the highlands. Geological controls (Brasil 1982, Ponce 1995) are responsible for the backwaters in the river channels with very low declivity, and the slow flow of water through the Pantanal.

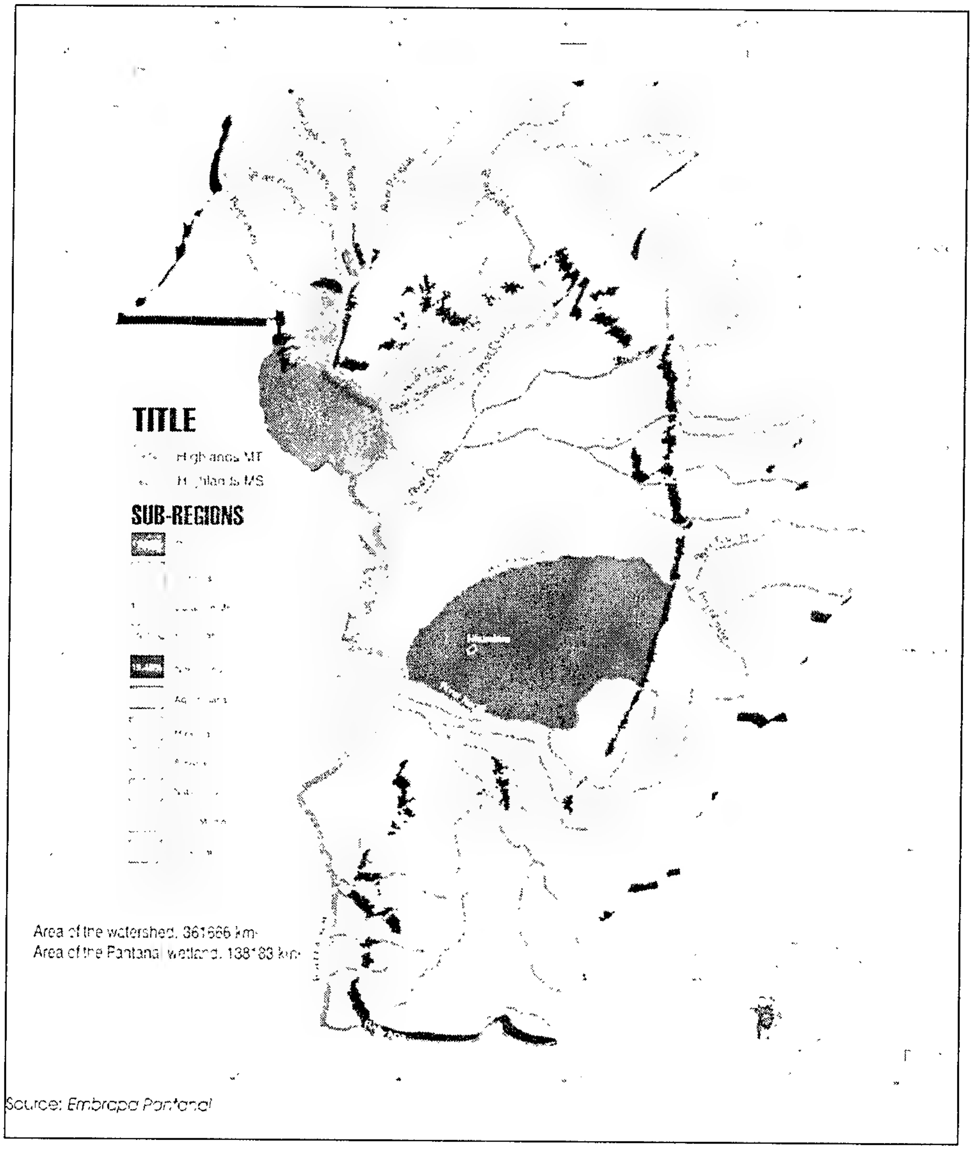

Figure 1. Map of the Pantanal, Upper Paraguay River Basin, Brazil

There is significant inter-annual variability in flood pulses. In 1988, the highest flood of the 20th century occurred; all the Pantanal seemed a big freshwater sea, justifying the ancient name of Xaraes Sea. In contrast, from 1960 to 1974, the floods were so low that the Pantanal appeared to be drying and becoming a large desert. The large flood of 1974 then surprised local people. Most ranchers were caught unawares, resulting in the deaths of many cattle. Native species were impacted as well.

Sandy soils predominate in almost the whole plain, excluding some areas in the southern part along the Miranda River, due to the Bodoquena calcareous mountains (Brasil 1979). Abundance of water, the flood pulses, high temperature and sun energy are responsible for the high productivity of the system, even in sandy soil conditions.

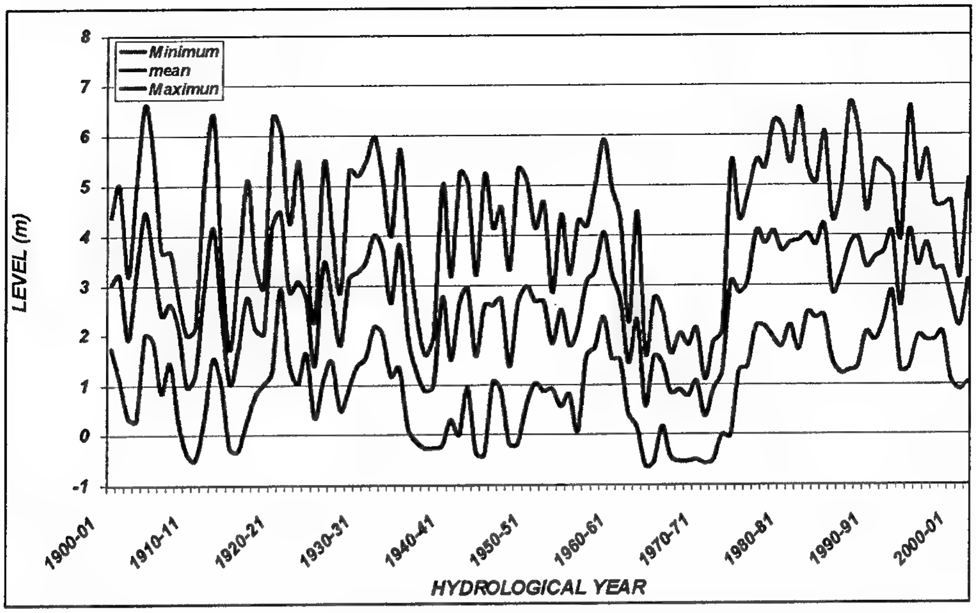

Figure 2. Annual Paraguay River water level at Ladário City, South Pantanal, Mato Grosso

The most visible characteristic of the Pantanal is a great diversity and abundance of wildlife. More than 600 species of birds have been identified (Thomás, pers. com.). This is one of the world's largest breeding grounds for wading birds and the most important area in South America for wetland birds. Over 250 species of fish have been identified (Britski et al. 1999) with about 10 species caught for commercial purposes. Richness and abundance of wildlife are the main features of the region, with approximately 90 mammal species, 162 species of reptiles, 45 amphibian species (Brasil 1997) and over 1,000 species of butterflies (Brown 1986). Wildlife species characteristic of the Pantanal include the giant anteater (*Myrmecophaga tridactyla)*, giant river otter (*Pteronura brasiliensis)*, capybara (*Hydrochoerus hydrochaeris),* tapir (*Tapirus terrestris*), jaguar (*Panthera onca palustris)*, puma *(Felis concolor*), caiman (*Caiman crocodilus yacare*), marsh deer *(Blastocerus dichotomus*), blue hyacinth macaw (*Anodorhynchus hyacinthinus*), jabiru stork (*Jabiru mycteria*) and woodstork (*Mycteria americana*).

Species at risk of extinction in other parts of Brazil that have healthy populations in the Pantanal region (Brasil 1997) include marsh deer (pampas deer (*Ozotocerus bezoarticus*), blue hyacinth macaw, jabiru stork, and capybara. Through aerial census, Mauro (1993) estimated a population of 136,000 marsh deer. Other species endangered elsewhere in Brazil that live relatively safely in the Pantanal include giant anteater, giant river otter, maned wolf, tapir, jaguar, puma, neotropical river otter (*Lutra longicaudis*) and bush dog (*Speothos venaticus*).

Water fluctuation, or flood pulse, regulates the ecological processes in the Pantanal. Fish production and migration, plant flowering, bird breeding, and caiman nesting are all strongly regulated and dependent on flood pulse. When water levels begin to decrease, migratory fishes (most of them of economic

value) start to shoal, and by the end of the dry season, generally by September/October, all of them are migrating upstream, forming spectacular shoals, like curimbata, *Prochilodus lineatus*, a very abundant detritivorous fish. After breeding on the upper reaches of the rivers, they again move downstream, by January/February and enter flooded areas to feed. A similar process occurs in alewives, which are carried passively by the river currents into the flooded areas, in which they find food and shelter. They stay in the inundated floodplain until water levels begin to decline. Adults return to the main channel by June/July, beginning another upstream migration.

Success of caiman nesting is also related to flooding intensity and duration. Low and short floods mean few nests and reduced breeding success. The same happens to piscivorous birds and mammals such as jabiru stork, woodstork, spoonbill, giant otter, and neotropical river otter. They are largely dependent on the flooding and subsequent drought that enable them to get enough food (fish) for their young and themselves.

Cattle ranching is the main economic activity in the Pantanal, traditionally owned by approximately 3,500 ranchers. The cattle are raised in a very extensive system (1 animal/3 hectares), based on native pastures. Some estimates show that, to be economically viable, each ranch needs at least 10,000 hectares (Cadavid-Garcia 1986).

Fishing is another traditional occupation performed presently by as many as 3,000 fishermen. Tourism is an increasing activity in the Pantanal, especially for sport fishing. In 1999, 59,000 tourists came to the South Pantanal just for fishing (Catella et al. 2002). This has provided employment for the local population, and business opportunities for the evolving tourism agencies, hotels, airway companies, local commerce, ships, boats, and so on. Also, ecotourism for photographing and sightseeing is increasing. Young European tourists engage in a special kind of tourism, referred to as "jungle" tourism.

Potential direct uses of Pantanal resources include management of natural populations of caiman for skin, meat, and other products, capybara for meat and leather, and feral pig for meat production. Ecological tourism is the primary indirect use of Pantanal natural resources. Research activities conducted by EMBRAPA-CPAP, at Corumbá, Matto brosso do Sul, provide a scientific foundation for development of regional guides, brochures, and books to supporting ecotourism.

The main challenge for sustainable use of the Pantanal is developing and disseminating a fundamental understanding of the primary ecological process that makes the Pantanal work. At the heart of this is the flood pulse concept described by Junk et al. (1989) — "*the principal driving force responsible for the existence, productivity and interactions of the major biota in river-floodplain systems is the flood pulse*"; *a predictable pulse of long duration engenders organismic adaptations and strategies that efficiently utilize attributes of the aquatic/terrestrial transition zone.*"

Relating the flood pulse concept to fish production and the diversity and abundance of detritivorous fish in the Pantanal, the author has concluded that the

richness and abundance of the fishery is related to detritus originating from the decomposition of terrestrial vegetation flooded during inundation. But it is also important to note that during the flood season, inundated terrestrial vegetation flowers and produces fruits and seeds that are eaten by the fishes. Further, the flooded vegetation (terrestrial and aquatic) acts as a filter, retaining detritus and other organic debris in its roots, stems, and leaves. A rich community of algae and microorganisms develops on this vegetation, providing food for small fishes. Flood pulses are essential for fish production. Higher floods result in greater fish production; lower floods, in lower fish production. Nutrients deposited by floodwaters and decomposition of aquatic vegetation support terrestrial vegetation growth in the dry season. Even with its poor soils, the Upper Paraguay basin incorporates and uses organic material in a very efficient way, yielding a rich biological diversity and productivity across its floodplains. The flooding also allows development of the aquatic vegetation that gives shelter and food for fishes. The flood pulse also explains the abundance of animals that depend on fish for their survival, such as caimans, fisheater birds (cormorants, jabiru, woodstork spoonbill, herons, etc.), giant otters and neotropical river otters.

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About the Author

Emiko Kawakami de Resende is a biologist with a Ph.D. degree who has been developing research since 1985 on the biology and ecology of freshwater fish for sustainable use, at Embrapa Pantanal. Dr. de Resende developed activities at CETESB (Environmental Sanitation Technology Company) with fishes and aquatic pollution in Sao Paulo State (1978-1980) and at INPA (National Institute on Amazonian Research, in Amazon State (1981-1985) with fishes and the impact of hydroelectric dams on fishes in the Brazilian Amazon.

6 Identification and Interaction Among Stakeholders of the Lake System Chacororé – Sinhá Mariana, Pantanal, Brazil (*Identificação e Interação entre Atores Sociais no Sistema Lagunar Chacororé – Sinhá Mariana, Pantanal, Brasil*)

Carolina Joana da Silva[1], José Mauro F. Silveira[2], Jane Simoni[1]
[1]Graduate Program in Ecology and Conservation of the Biodiversity, Federal University of Mato Grosso (UFMT) and State University of Mato Grosso (UNEMAT), 562 Rua 49, Cuiaba, Mato Grosso, Brazil e-mail: *ecopanta@terra.com.br*
[2]CET -- University of Brasilia, Centro de Excelência em Turismo,[1] Campus Universitário Darcy Ribeiro L3 Norte 70.910-900 Telephone: 307-2942 Fax: 307-2943. e-mail: *cetmkt@unb.br http://www.unb.br/cet/*

Abstract (*Resumo*)

The Pantanal is the largest flooded plain in the world; it reaches approximately 140,000 km^2, sheltering a mosaic of different habitats, which sustains a rich aquatic and terrestrial biota. Lakes Chacororé and Sinhá Mariana

[1] The Excellence Tourism Center is a department within the University of Brasilia, created with the objective of training, forming and capacitating professionals to the industry of tourism, hospitality, and gastronomy.

are characterized by a multiplicity of habitats, recognized for their aquatic productivity, scenic beauty, and outstanding tourism potential. Lakes Chacororé and Sinhá Mariana have been a constant target of conflicts of interest between the many users, including fishermen, environmental agencies, hotels, tourists, and NGO´s. This article identifies the stakeholders of Lakes Chacororé and Sinhá Mariana and defines levels of interaction among them. The results show different interests that when placed in a continuum range from international to local onsite. The number of local onsite stakeholders increases as well as the diversity of interests, emphasizing the dependency that this group has on the system, especially on fishing aspects. The interactions indicate both conflict and cooperation among the stakeholders.

O Pantanal é a maior área alagável contínua do mundo, alcançando aproximadamente 140,000 Km². O Pantanal abriga um mosaico de diferentes habitats, os quais sustentam uma rica biota aquática e terrestre. O sistema de baías Chacororé -Sinhá Mariana é caracterizado por uma multiplicidade de habitats, reconhecido por sua produtividade aquática, beleza cênica e incontestável potencial turístico. Este sistema de baías tem sido alvo constante de conflitos de interesse entre os grupos sociais, tais como pescadores, órgãos ambientais, hotéis, turistas e ONGs. Este artigo identifica os grupos sociais do sistema de baías Chacororé-Sinhá Mariana e define os níveis de interação entre eles. Os resultados mostram diferentes interesses que variam em um "continuum" desde o nível internacional até o local. O número de grupos e interesses locais é naturalmente maior, o que mostra a dependência que tais atores sociais têm em relação ao sistema, pescadores em particular. As interações registradas indicam tanto relações de conflito, quanto cooperação entre os diferentes grupos sociais.

Key Words

Pantanal Wetlands, Stakeholders, Chacororé and Sinhá Mariana lake system (*Pantanal, Stakeholders, sistema de baías Chacororé e Sinhá Mariana*)

Introduction

The Pantanal is the largest flooded plain in the world; it reaches approximately 140,000 km², sheltering a mosaic of different habitats, which sustains a rich aquatic and terrestrial biota. The Pantanal is considered by Olson et al. (1998) to be of "global distinction, vulnerable and of great priority to conservation on a regional scale." The fragile equilibrium of the Pantanal ecosystem, maintained by the flood pulse, is threatened by current economic policies. Navigation on the Paraguay River, roads, and construction of dikes are the greatest challenges within the Pantanal. Other contributing factors are deforestation, modification of the geo-hydrology of rivers by dams and alteration of natural vegetation at the headwaters that feed the Pantanal (Brazil 1999, Da Silva et al. 2001).

The Pantanal within the state of Mato Grosso is characterized by a multiplicity of habitats, such as the system of Lakes Chacororé and Sinhá Mariana, associated to the Cuiabá River. This system is recognized for its aquatic productivity, scenic beauty, and outstanding tourism potential. This diverse system of lakes is interconnected through *corixos*, small and meandered channels, which support a high biological productivity capable of sustaining thousands of bird species, isolated or grouped in colonies that gather themselves in nocturnal roosts.

Because of their high fishing and tourism potential, Lakes Chacororé and Sinhá Mariana have been the constant target of conflicts of interest between the many users, including fishermen, environmental agencies, hotels, tourists, and NGO's. Da Silva et al. (1998) and Da Silva (2000) discuss these challenges and recommend greater participation of society in seeking out solutions to these challenges on the conservation of the water and biodiversity of the Pantanal. The Chacororé-Sinhá Mariana lake system serves well as a microcosm of the Panatanal, given the well-represented habitats present in the system, aquatic productivity, environmental impacts and the diversity of stakeholders and interests.

The authors' studies in the Chacororé-Sinhá Mariana lake system seek to answer the following questions:

- Who are the present stakeholders in the system?
- What are the stakeholders' interests in the system?
- What activities cause conflicts among the stakeholders?
- What spatial and temporal changes are observed in the system?
- What are the levels of interaction, and the relation of competition and collaboration among the stakeholders?

This article answers the first three questions of the "stakeholder analysis" of the Chacororé-Sinhá Mariana lake system. Stakeholder analysis methodology proposed by Grimble et al. (1994, 1995) and Grimble and Chuan (1995) was used to answer these questions.

Study Area

The system of lakes or bays known locally as Chacororé-Sinhá Mariana is imbedded in the Pantanal landscape. Chacororé-Sinhá Mariana is located to the left margin of the Cuiabá River between the coordinates 16° 14' a 16° 16' latitude South e 55° 55' a 55° 58' longitude West (Figure 1) in the municipalities of Santo Antônio do Leverger and Barão de Melgaço (Da Silva and Figueiredo 1999).

During the flood season the Chacororé and Sinhá Mariana Lakes interconnect through the floodplain; they are independent during the dry season.

Chacororé Lake has an area of approximately 65 km^2, measured during the flood season by Pinto-Silva (1980) and connects to the Cuiabá River only during the flood season through small river channels called *corixos* (Da Silva and Figueiredo 1999). The Sinhá Mariana Lake is constantly receiving water from the Mutum River; the lake is an enlargement of this river channel, and is connected to the Cuiabá River throughout the year (Da Silva and Figueiredo 1999). According to Pinto-Silva (1980), Sinhá Marina Lake is approximately 11.25 km^2 during the flood season.

According to Silveira (2001) the system of lakes has been suffering from human impacts, such as a great influx of tourist and fishing boats, the building of artificial dikes to contain the water flow within the lake, and the construction of mansions that are prohibited by law (Figure 2).

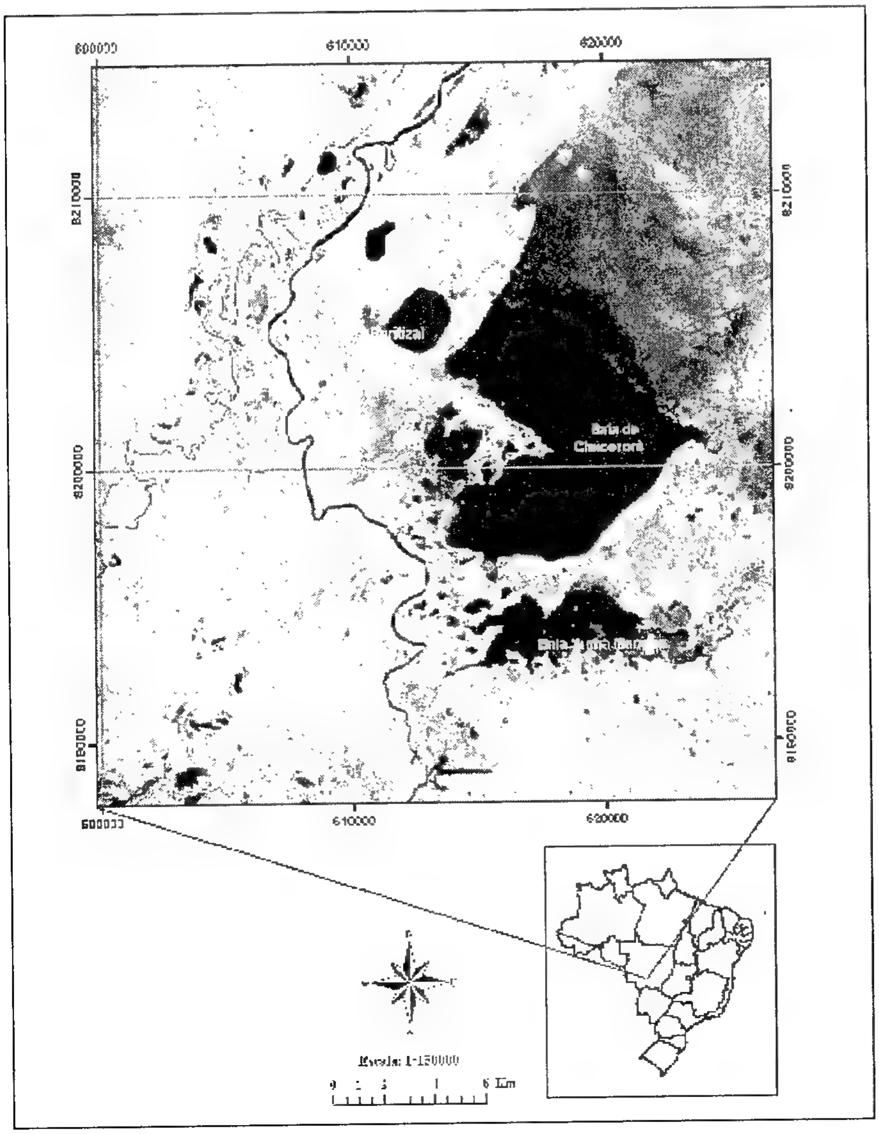

Figure 1. Study area, Lakes Chacororé and Sinhá Mariana and the Cuiabá River

Figure 2. Lakes Chacororé and Sinhá Mariana. Arrows indicate the main causes of conflicts among stakeholders and ecological changes (yellow arrows: artificial dikes, green arrow, permanently flooded area (interannual floods), white arrow: illegal construction of mansions, orange arrow: silting)

Identification and Interest of Stakeholders in Lakes Chacororé and Sinhá Mariana

The diversity of habitats and scenic beauty present in Lakes Chacororé and Sinhá Mariana also shelters an array of stakeholders who have been placed in a continuum of five levels: Global and International, National, Regional, Local Offsite, and Local Onsite. Each level carries special features, including unique characteristics of environmental interest. These, in turn, generate unique interactions that define the levels of relation (Table 1).

At the Global/International level we encounter multilateral agencies such as the Inter-American Bank, which finances the Pantanal Program. The primary stakeholder at the National level is the National Environmental Ministry (MMA and IBAMA), which plays a role in the enforcement of existing environmental laws. The Public Ministry monitors whether governmental agencies are fulfilling their role. As the Pantanal is considered a National Heritage Site by the Brazilian constitution, conflicts that occur in this system of lakes attract significant media attention.

National tourism is increasing in the Pantanal region, attracting people from different parts of the country, as shown by Silveira (2001), Garcia (2000), and La Capra et al. (1999).

Table 1
Stakeholders, Lakes Chacororé and Sinhá Mariana

Continuum level	Stakeholders	Environmental Interest
Global and International	Multilateral Agencies	Conservation, sustainable development, tourism development, economic gain
National	National Environment Ministry (MMA and IBAMA), Public Ministry, Press/media, tourists	Conservation, protection of resources, tourism development, law enforcement
Regional	State Environment Agencies (FEMA); tourists, Forest Police, press	Conservation, law enforcement, tourism development, economic gain
Local, offsite	Local officials, universities, NGOs, tourism guides, fishermen	Conservation, access to resources, tourism development, protection of resources, economic gain
Local, onsite	Sport, professional, and subsistence fishermen; hotel and landowners; boat pilots; traditional communities; farmers; bait collectors; community associations	Conservation, economic gain, food, interaction with nature and wildlife, access to resources, tourism development, land for cultivation, attractive places

At the regional level, the State Environmental Agency – FEMA, controls environmental actions and enforces state laws. The Forest Police is the governmental branch that executes enforcement. In the same way that the Pantanal attracts tourists at the international and national levels, regional tourists are also present in the system. Silveira (2001) shows that the press released news on constructions, dikes, tourism, enforcement, traditional communities, and boats. The same author found an increase in the number of articles published exclusively on the system of lakes.

Local offsite stakeholders include local officials, universities, NGOs, tourism guides, and fishermen. Their interests are linked to conservation, access to resources, tourism development, protection of resources, and economic gain. Local onsite stakeholders include sport, professional and subsistence fishermen, hotel and land owners, boat pilots, housewives, traditional communities, farmers, bait collectors, and community associations. Their interests range from conservation to economic gain, food access, interaction with nature and wildlife, access to resources, tourism development, land for cultivation, and aesthetics. The number of local onsite stakeholders increases as does the diversity of interests, emphasizing the dependency that this group has on the system, especially on fishing aspects.

The placement of each stakeholder within the spectrum that ranges from global to local allows for a better perspective of what is at stake within the system. Inferences as to who wants what from the system can be drawn, as can inferences of how to accomplish the common interest of conservation and tourism, which permeates the whole continuum. The diversity of kinds, roles, and functions of stakeholders shows the necessity of an approach that contemplates linkages among agencies to achieve a sustainable management system.

Interaction Among Stakeholders

The interaction among some stakeholders within the lake system reflects the complex dynamics of the network (Figure 3). In the lake system, the stakeholders have many interests, some of them have a high control on the activities, such as the Public Ministry and the State Environmental Agency, followed by the fishermen. The media has medium to high control on these activities, while the others have smaller controls.

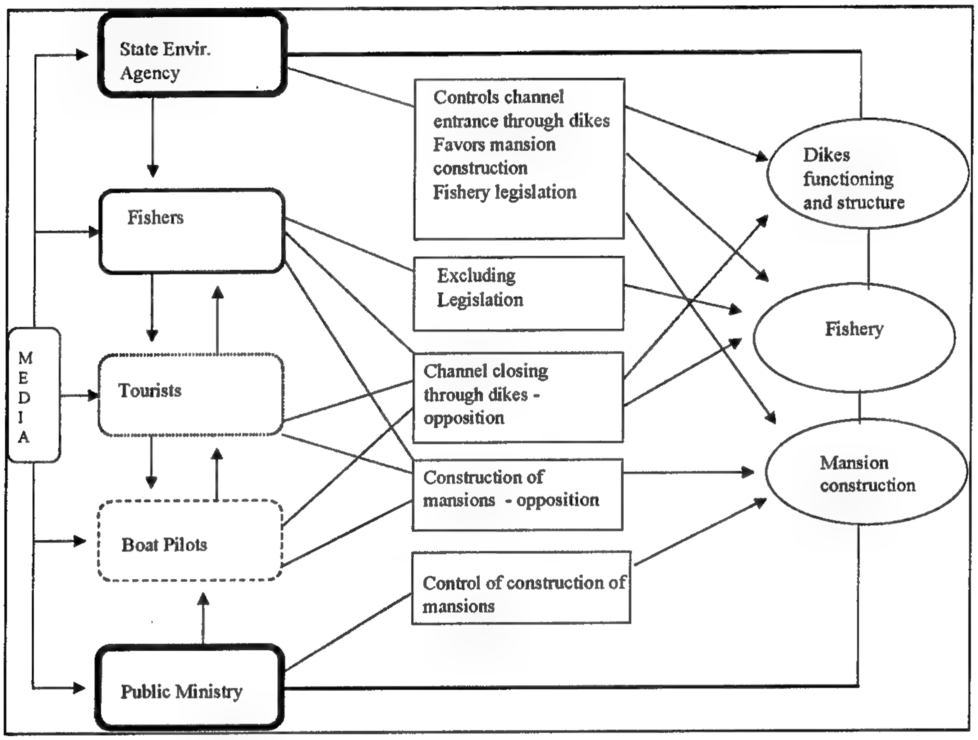

Figure 3. Interaction among stakeholders in Lakes Chacororé and Sinhá Mariana

The Public Ministry controls mansion construction and the State Environment Agency controls dikes functioning and fisheries. However, the Public Ministry also has some control over the State Environmental Agency. The actions of this agency have favored enforcement for some stakeholders such as the fishermen and, on the other hand, seemed to benefit mansion builders. The local newspapers showed this contradiction (Silveira 2001). This condition may reflect the stakeholders' organizations, and their political and economic conditions, which increases conflicts among them, leading to social inequality.

Fishermen, tourism guides, and boat pilots share some interests, indicating their place within the context of economic and political conditions, urging empowerment of these stakeholders. In the face of this common interest, these stakeholders also may be of great support in a management plan due to their collaboration potential.

Final Remarks

This study indicates that stakeholders at the base of the social pyramid and with greater dependency on local biodiversity for subsistence, food, leisure, and tourism are submitted to pressures from all other stakeholders, from the international to within their own placement on the continuum, local offsite or onsite. A proactive agenda should be implemented in a way that benefits these social groups and improves their capacity of social insertion to influence decision making on public policies that affect their biological and cultural life strategies.

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About the Authors

Carolina Joana da Silva, Ph.D., biologist, received her doctorate in Ecology and Natural Resources Conservation from the Federal University of São Carlos, São Paulo. She is the author of several articles, chapters, and a book on the Pantanal Wetland. She was the former Coordinator of the Gran Pantanal Ecology Project, a Brazilian – German cooperative effort from 1991-2000. Carolina teaches Biodiversity Conservation and Etnoecology at the Ecology and Biodiversity Conservation Graduate program of the Federal University of Mato Grosso. Currently, she coordinates the Research Center of Limnology and Biodiversity of the Pantanal, at the State University of Mato Grosso. The main focus of her current work is to understand ecological processes related to the Flood Pulse in the Pantanal Wetland landscape and the application of this concept to conservation and management, as well as the dynamics of human change.

José Mauro F. Silveira has a Masters degree in Ecology and Conservation of the Biodiversity. He taught science classes for many years. Currently, he coordinates the Eco-Tourism program at the Excellence Center of Tourism of the University of Brasilia.

Jane Simoni acquired her B.A. degree in socio-cultural anthropology at Fort Lewis College, in Durango Colorado, USA. Her Masters from the Federal University of Mato Grosso is in Ecology and Conservation of the Biodiversity. She is currently researching the socio-ecological impacts of a dam on a downstream traditional riverine community.

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About the Authors

Carolina Joana da Silva PhD, biologist, received her doctorate in Ecology and Natural Resources Conservation from the Federal University of São Carlos, São Paulo. She is the author of several articles, chapters and a book on the Pantanal Wetland. She was the former Coordinator of the Gran Pantanal Ecology Project, a Brazilian-German cooperative effort from 1991-2000. Carolina teaches Biodiversity Conservation and Etnoecology at the Ecology and Biodiversity Conservation Graduate program of the Federal University of Mato Grosso. Currently, she coordinates the Research Center of Limnology and Biodiversity of the Pantanal, at the State University of Mato Grosso. The main focus of her current work is to understand ecological processes related to the Flood Pulse in the Pantanal Wetland landscape and the application of this concept to conservation and management, as well as the dynamics of human change.

José Mauro F. Silveira has a Masters in Ecology and Conservation of the Biodiversity and taught science classes for many years. Currently, he coordinates the Eco-Tourism program at the Excellence Center of Tourism of the University of Brasilia.

Jane Simoni acquired her BA in socio-cultural anthropology at Fort Lewis College, Durango, Colorado, USA. Her Masters from the Federal University of Mato Grosso is in Ecology and Conservation of the Biodiversity. She is currently researching the socio-ecological impacts of a dam on a downstream traditional riverine community.

7 The Pantanal Ecology Project: Challenges and Progress of a Brazilian-German Scientific Collaboration (*O Projeto Ecológico Pantanal: Desafios e Resultados em uma Colaboração Científica Brasil-Alemanha*)

Catia Nunes da Cunha[1], Karl Matthias Wantzen[2], and Wolfgang J. Junk[2]
[1]Federal University of Mato Grosso, Instituto de Biociências, Núcleo de estudos ecológicos do Pantanal (NEPA), Cuiabá-MT. 78060-900. Brazil. email: *catianc@terra.com.br*
[2]Max-Planck-Institut fuer Limnologie, AG Tropenoekologie, 24302 Ploen, and Konstanz University, 78547 Konstanz, Germany. email: *wantzen@mpil-ploen.mpg.de* and *wjj@mpil-ploen.mpg.de*

Abstract (*Resumo*)

Since 1991, Brazilian and German researchers of the Pantanal Ecology Project (PEP [a cooperative effort between the Federal University of Mato Grosso, UFMT, and the Max-Planck-Institute of Limnology, MPIL]) have been studying the structures and functions of the various ecosystem types of the Pantanal. This work focused on delivering a solid scientific database for proposing management concepts and conservation plans, including analysis of environmental impacts and their socio-economic effects. The interdisciplinary approach is based on the flood pulse concept (Junk et al. 1989), which uses the annual hydrological changes as the driving force for patterns and processes in floodplain ecosystems. Limnologists, plant ecologists, zoologists, and

geographers cooperate in selected landscape units such as floodplain lakes, an inundation gradient, a bird breeding site and the catchments of tributaries to the Pantanal. In the past 10 years, PEP has contributed more than 100 scientific publications on this issue (see homepage *http://www.mpil-ploen.mpg.de/mpilts2d.htm*). Scientific education is one important pillar for the sustainable transfer of acquired knowledge into society. In a training course at the UFMT set up by PEP in 1994, 150 students performed studies in wetland ecology to obtain their Ph.D., M.Sc., or B.Sc. degrees. During this time, laboratories and field stations were established to enhance scientific infrastructures. The Brazilian-German cooperation on the Pantanal has now become the intellectual nucleus for the establishment of the United Nations University – Pantanal Regional Environmental Program at the UFMT. Analyzing the effects of changes in the flooding regime in the Pantanal will form the focus of future cooperative research.

Desde 1991 o Projeto Ecologia do Pantanal (PEP) [uma cooperação científica entre a Universidade Federal de Mato Grosso e o Instituto Max-Planck de Limnologia] vem envidando esforços para entender a estrutura e o funcionamento dos ecossistemas pantaneiros e os desafios sócio-ambientais impostos a este sistema. Nosso trabalho tem enfocado na produção de uma sólida base científica para propor conceitos de manejo e planos de conservação, incluindo a análise de impactos ambientais e seus efeitos sócio-econômicos. A filosofia científica do PEP seguiu a abordagem interdisciplinar para melhorar o entendimento das interdependências entre os organismos (incluindo o ser humano) e o meio ambiente. Esta abordagem está fundamentada no conceito do pulso de inundação (Junk et al. 1989).

Nos últimos dez anos, PEP contribuiu com mais de 100 publicações (http://www.mpil-ploen.mpg.de/mpilts2d.htm). A educação científica é um pilar importante para a transferência sustentável de conhecimento adquirido para a sociedade. Por isso o PEP investiu na capacitação de recursos humanos, no âmbito da ecologia de área alagáveis e até 1994 cerca de 150 estudantes obtiveram seus títulos de doutor, mestre e/ou de graduação em treinamento relacionado ao projeto. Durante este tempo, laboratórios e estações de campo foram implementados como infra-estrutura para a pesquisa científica. A cooperação brasileira-alemã no Pantanal se tornou um núcleo intelectual de destaque na ciência ecológica regional e possibilitou à UFMT viabilizar junto à ONU - UNESCO o estabelecimento do Programa PREP - Pantanal Regional Environmental Program. A análise dos efeitos de mudanças no regime de inundação no Pantanal será o foco de futura pesquisa cooperativa.

Key words

Scientific cooperation, Pantanal, Mato Grosso, wetland, floodplain, sustainable management, conservation (*cooperação científica, Pantanal, Mato Grosso, área úmida, planície de inundação, gestão sustentável, conservação*)

Introduction

The Pantanal of Mato Grosso is an extraordinary landscape. It ranks as one of the largest wetlands of the world and harbors immense populations of rare species. Situated in the heart of South America, it is a biogeographical turntable of Amazonian forest basins and savanna/Cerrado biomes. The fluctuation between flooding and dryness, traditional land-use practices, and difficult access have guarded its wilderness and biodiversity over centuries. In the past 30 years man-made environmental impacts have begun to threaten its ecological integrity by changing the hydrological patterns, destroying the natural vegetation, and polluting the waters with toxic substances, wastewater, and excessive sediment loads (Alho et al. 1988, Coy 1991, Hamilton 1999).

Efforts are needed to preserve the fauna and flora of the Pantanal, reduce detrimental impacts, and devise judicious management practices that enable a part of the natural resources to be used without destroying the natural dynamics that maintain the ecosystem. These efforts can only be realized if the patterns and processes of the system are known and if there are highly skilled personnel available for both study and application. These are the goals of the Pantanal Ecology Project (PEP; Projeto Ecologia do Gran Pantanal), a Brazilian–German scientific collaboration.

Researchers of the Federal University of Mato Grosso (UFMT) have been studying the Pantanal since the founding of the university in 1970. In 1988, members of the university, the state environmental agency FEMA, and non-governmental organizations searched for collaborators at German research institutions to carry out a combined basic and applied research project. They found a strong partner for this enterprise in the Tropical Ecology Research Group of the Max-Planck-Institute of Limnology (MPIL), Plön, Germany, and initiated the PEP.

The project has been designed as part of the SHIFT program (Studies of Human Impacts on Forests and Floodplains in the Tropics), which has existed since 1989 as an agreement between the Brazilian and German governments, represented on the Brazilian side by the Research Council (Conselho Nacional de Desenvolvimento Científico e Tecnológico, CNPq) and the Federal Agency for Conservation and Management of Renewable Natural Ressources (Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis, IBAMA) and on the German side by the Ministry of Education and Research (Bundesministerium für Bildung und Forschung, BMBF).

Three specific work fields were organized: 1) basic and applied research to resolve existing environmental problems, 2) elaboration of proposals for the sustainable management and protection of natural resources, and 3) improvement of infrastructure and training of human resources.

The PEP aims to contribute to these goals through ecological research on savanna floodplains, training young professional scientists, and consulting governmental and non-governmental institutions that deal with the management and conservation of the Pantanal. The work is focused on delivering a solid

scientific database for proposing management concepts and conservation plans, including analysis of environmental impacts and their socioeconomic effects.

Study Area

The Pantanal of Mato Grosso is situated in the Alto Paraguay depression, which extends between the old crystalline shield of central Brazil and the geologically young uplifting Andes. The main phase of the subsidence resulting in the wetland depression is very likely related to the last compression pulse in the Andes during the upper Pliocene–lower Pleistocene, ca. 2.5 million years ago. Lying 15–20° south of the Equator, the Pantanal is situated in a circum-global belt of climatic instability. Dramatic climate changes during the Quaternary led to a different discharge pattern of the Paraguay River and its tributaries and to different erosion and sedimentation patterns inside the Pantanal (Junk et al., *in press*). Because of these distinct geological and hydrological characteristics, subregions of the Pantanal were established along the floodplains of its feeder rivers (Adámoli 1981; Hamilton et al. 1996). The research of PEP concentrated on the Pantanal of Poconé, the Pantanal of Barão de Melgaço, and the tributaries leading to the Pantanal (Figure 1).

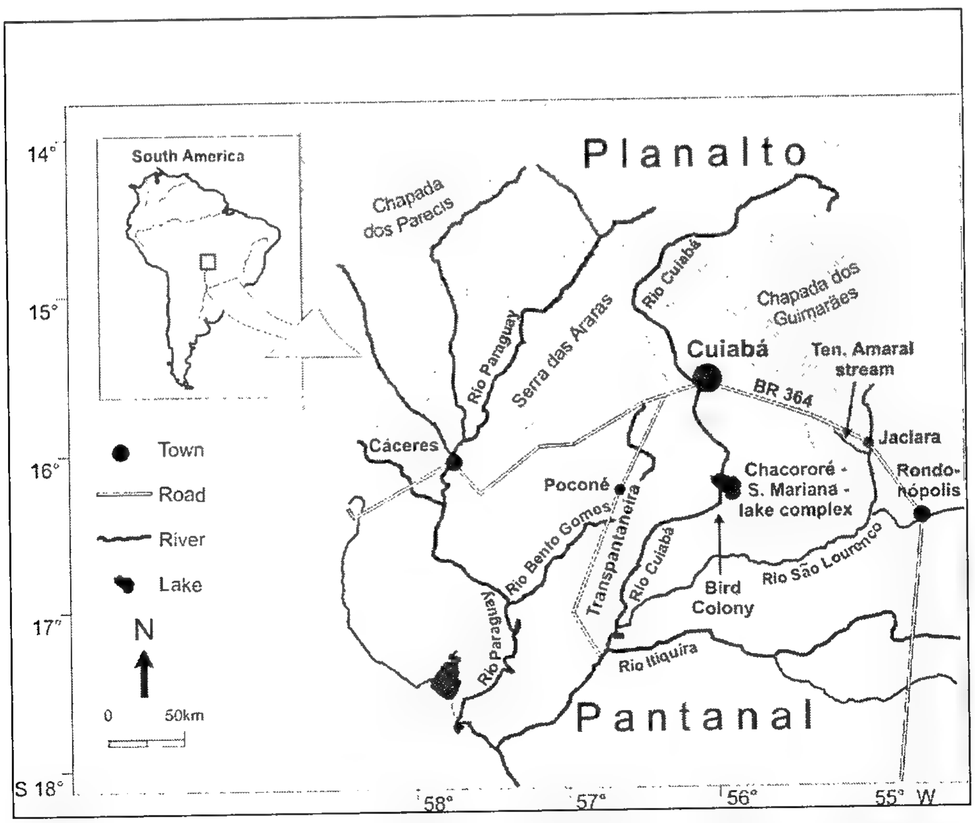

Figure 1. Map showing the position of the research site within Brazil (insert) and in the catchment area of the Paraguay River. The high plains, which originally had Cerrado vegetation, are shaded dark gray (Planalto), and the Pantanal wetland is shaded light gray

For ecological research, management planning, and conservation, it must be understood that the Pantanal, which is intrinsically linked to the catchment areas of its feeder rivers, e.g., the Paraguay, Cuiabá, São Lourenço, Taquari, Itiquira, and Negro Rivers, is strongly influenced by the natural and human-induced processes that occur in these areas. These areas — the Planalto — are situated 150–500 m above the Pantanal wetlands. There is an active exchange between the animal and plant populations of the Planalto and the Pantanal. Many Pantanal fish species migrate into the upper reaches of the feeder rivers for spawning (Figure 2a). The basin-shaped wetland receives water and suspended and dissolved solids from the Planalto. Here, many environmental problems in the Pantanal have their origin, e.g., the outputs from intensive farming, ranching, and urbanization (Figure 2b).

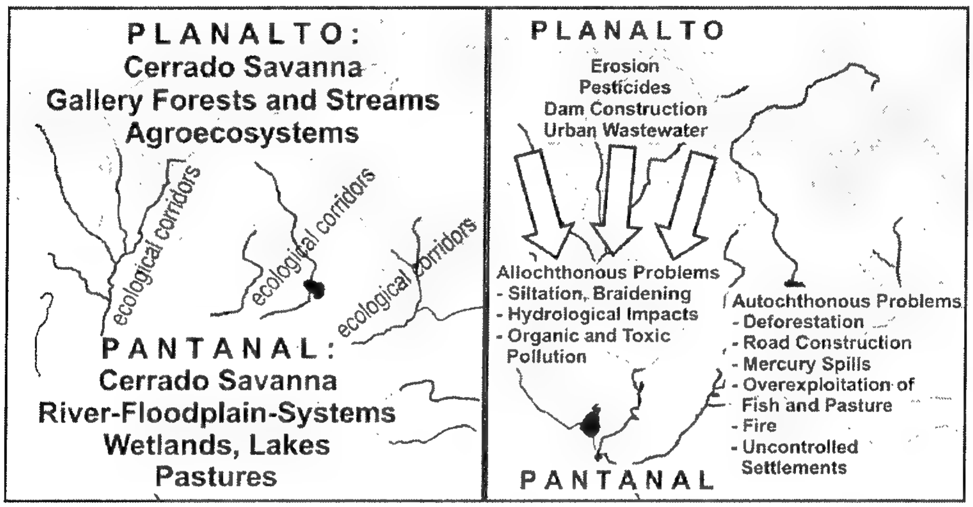

Figure 2. The same area shown in Figure 1, but indicating (a) the connectivity of populations of the Pantanal and the Planalto, and (b) the export of pollution from the catchment area into the wetland

Scientific Approach

The scientific philosophy of the PEP is a holistic approach to understand the principal structures and functions of the ecosystem and the human activities affecting it. This approach is based on the Flood Pulse Concept (FPC) (Junk et al. 1989) and its follow-ups (Junk and Wantzen 2003), which use the annual hydrological changes (flood pulse) as the driving force for patterns and processes in floodplain ecosystems, and which oscillate between aquatic and terrestrial phases. An Aquatic Terrestrial Transition Zone (ATTZ) couples permanent aquatic and terrestrial habitats. The largest part of the Pantanal is an ATTZ; only few elevations remain dry during the flooding, and few lakes and rivers sustain aquatic life during the dry season. However, the extension of the ATTZ varies over years, and there are multi-annual cycles of drier and wetter conditions in the Pantanal.

To investigate the FPC in the Pantanal, limnologists, plant ecologists, zoologists, and geographers cooperate in selected landscape units, such as

floodplain lakes, an inundation gradient, a bird breeding site, and the catchment of tributaries leading into the Pantanal. The scientific activities and training of human resources follow four lines of research:

- Biodiversity (biotic patterns).
- Ecological processes.
- Abiotic patterns.
- Man–environment relationships.

The results are applied for the development of sustainable management concepts and conservation programs. In the past 12 years, the PEP has contributed over 100 peer-reviewed publications and numerous congress contributions (see *http://www.mpil-ploen.mpg.de/ mpilts2d.htm*).

Results of the PEP (Early work)

When the project started, the state of knowledge of the Pantanal was rather meager. Thus, the aim of the PEP during the first phase (1991–1996) (Figure 3) was a qualitative and quantitative description of the ecosystems in the Pantanal wetland, with an emphasis on limnology, botany, remote sensing, and environmental impact assessment. Undisturbed parts of ecosystems were compared to those showing different degrees of alteration by human impacts in order to elucidate the impact of land use and its role in the degradation of ecosystems.

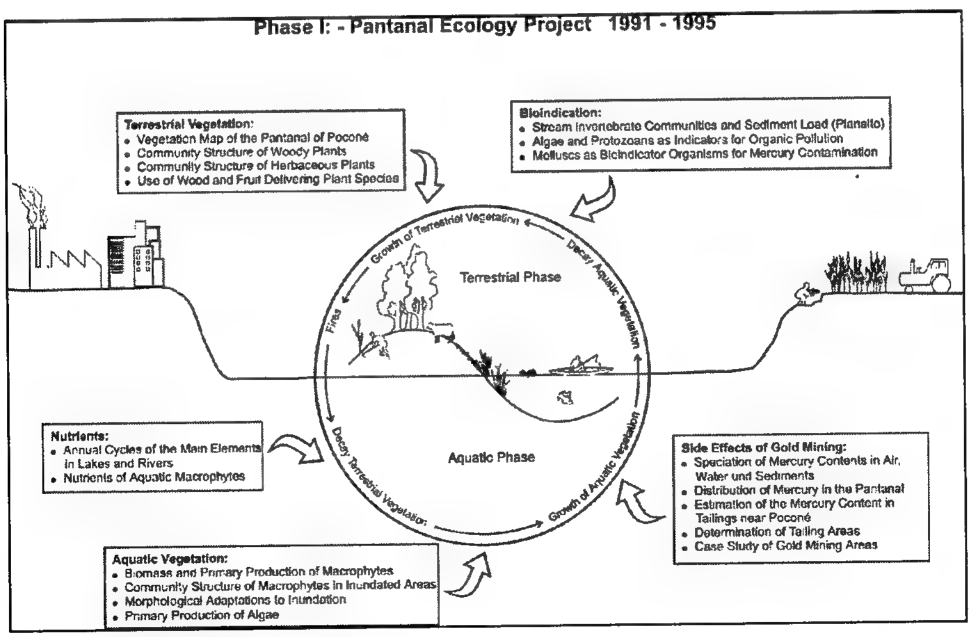

Figure 3. Goals of the first phase of the Pantanal Ecology Project, a Brazilian-German scientific collaboration

The diversity of the communities of herbaceous and woody plants was described in several case studies within the floodplain (Lemes do Prado et al.

1994; Schessl 1997, 1999; Nunes da Cunha 1998). These data were compared with environmental factors, such as flood pulse and soil composition (Almeida 1998; Nunes da Cunha 1998; Penha et al. 1998a, b; Zeilhofer and Schessl 1999).

The limnology of the aquatic habitats was characterized, including water chemistry, primary production, and morphological patterns (da Silva and Esteves 1993, 1995; Heckman 1994), and various microbiota and invertebrate communities were described (rotifers [Turner and da Silva 1992, Kretzschmar 1993]), testaceans [Hardoim and Heckman 1996, Heckman 1998]). A paramount result of the limnological studies was that the flood pulse — the change between the aquatic and terrestrial phases — is the driving force for the rapid recycling of the nutrients of this nutrient-poor system and allows the maintenance of its productivity and biodiversity (Heckman 1994; da Silva and Esteves 1993, 1995; da Silva et al. 1994; De-Lamônica-Freire and Heckman 1996).

Satellite imagery aided in the extrapolation of the results to landscape scale and the visualization of alterations of landscape units caused by human impact or by inundation (Rawiel 1993, Plá 1998, Zeilhofer 1996, Zeilhofer and Schessl 1999, Schwenk 1998). A vegetation map of the northern Pantanal was made (Nunes da Cunha et al. 1995); today, this map serves as a basis for environmental planning of the region.

Bioindicator systems were identified to assess impacts of eutrophication using euglenophyte algae (Heckman et al. 1996), testaceans (Hardoim and Heckman 1996), and benthic invertebrates (Paula 1997), as well as for habitat deterioration caused by erosion in the plateaus above the Pantanal using benthic invertebrates (Wantzen 1997, 1998a, 1998b) and for mercury using mussels (Callil 1996; Callil and Junk 1999, 2001).

Mercury content was measured in different environments to assess the impacts of mercury contamination from gold mining (Tümpling, Jr. et al. 1995a, 1995b; Tümpling, Jr. 1995). Social consequences of mercury spills were evaluated in a functional ecosystem analysis (Nogueira and Papadimacopoulos 1994; Nogueira 1995; Nogueira et al. 1997a, 1997b; Nogueira and Junk 2000).

Interdisciplinary Studies (Subsequent work)

Based on the results of the first years, the second phase of the PEP began (1997–2001), which included interdisciplinary research on key habitats, case studies on keystone and bioindicator species for biological integrity, and assessment of environmental impacts on the Pantanal ecosystem and adjacent catchment areas (Figure 4). The interdisciplinary work was grouped into four categories: erosion and sedimentation, keystone and bioindicator species, key habitats, and tourism and fisheries.

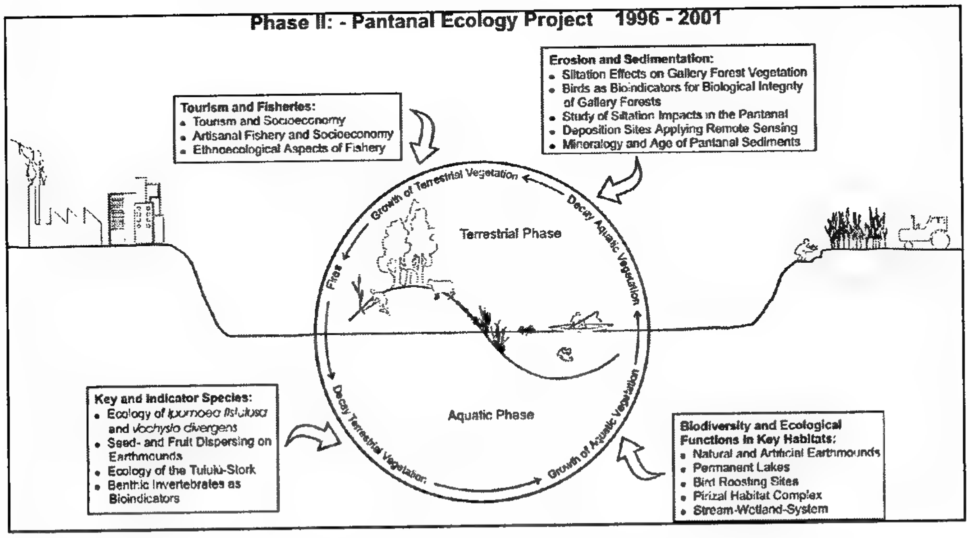

Figure 4. Goals of the second phase of the Pantanal Ecology Project, a Brazilian–German scientific collaboration

Erosion and sedimentation

The dramatic effects of erosion in the catchment areas caused by turning the Cerrado into an agro-industrial landscape were revealed during the first phase (Wantzen 1998b) and were specified with regard to the soil properties and plant communities. Soil and vegetation cover of a selected catchment area (Tenente Amaral, Jaciara, Mato Grosso) were mapped, applying satellite imagery (Landsat TM), aerial photographs, and ground truth; and five classes of natural vegetation, three classes of secondary vegetation, and four artificial areas were defined (Barros 1998). In the same area, the swamp forest phenology and the fluctuation of the water table in different soil types were studied (Monteiro, unpublished).

Lowering of the groundwater level from erosion gullies can cause grasslands along the waterlogged margins of streams to become overgrown by bushes, thus changing the structure of this habitat (Wantzen and Nunes da Cunha, unpublished). Recuperation strategies have been developed for the erosion gullies (Rodrigues et al. 1999) and for the buffer zones between agricultural land and streamside wetlands (Wantzen 2002). Bird species were identified as bioindicators for the ecological integrity of gallery forests in the Pantanal (Petermann 2002). Gallery forests and their stream–wetland systems provide ecological corridors and harbor a very diverse flora and fauna. They serve as a model for new concepts in running-water ecology (Wantzen and Junk 2000; Junk and Wantzen 2003).

In addition to erosion, the agrochemicals from the large agro-industrial areas on the Planalto cause potential impacts in the Pantanal. While no signs of eutrophication could be found in tributaries of the feeder rivers caused by diffuse input of fertilizers (Wantzen 1998a), there is reason to assume that pesticides are transported towards the Pantanal (Alho et al. 1988). The degradation of pesticides has been shown to depend on soil organic matter, which occurs in very low concentrations in Cerrado soils (Laabs et al. 2000); therefore, seepage of these substances into the groundwater is possible. While the river water

contained measurable, but rather low concentrations of pesticides, the high concentrations in rainwater indicate that rain is a potential vector for the transport of pesticides into the Pantanal (Laabs et al. 2002).

The Pantanal basin serves as a sink for the sediments derived from erosion in the Planalto. Quaternary sequences were studied by Irion and coworkers in order to determine the age of the sediments and their precise origins (Buchas and Irion 2000). Based upon the results obtained, they critically revised the concepts of paleodunes (Klammer 1984) in the Pantanal (Colinvaux et al. 2001).

Keystone and bioindicator species

The ecology of a few species can be linked closely with many others to the extent that these few species become key elements of the communities, the so-called keystone species. Keystone species include insects and birds as pollinators and seed dispersers, carnivores as predators at the top of the food chain, and many plants that provide resources for many other species.The concept of bioindicator species can be used for species that are sensitive to chemical toxins and serve to monitor the health of the environment, or for species that are targeted for conservation because preserving habitat for them preserves an entire biological community and the associated ecosystem processes.

The Tuiuiu stork (*Jabiru mycteria*) has been studied as a bioindicator species of the Pantanal wetland. Since the stork migrates, its requirements comprise various aspects of habitat quality (e.g. nesting trees, low-water foraging areas) covering vast regions. A total of 68 nests and their respective tree species were monitored for three years (Oliveira 1998, Oliveira and Da Silva 1998). It was proven that electric lines along the Transpantaneira Highway cause high mortality in Tuiuiu and other large wading birds. As a result of this study, the responsible energy company has made all electric lines in that area safe (Oliveira 2000), and this example will be followed in the entire Pantanal.

A keystone species is the palm tree *Scheelea phalerata*, which is the food source for the hyacinth macaw, an endangered species of parrot (Pinho 1998), and which harbors a large variety of invertebrates (Brizzola 2001, Battirola 2002, Marques et al. 2001).

Key habitats

The Pantanal wetland is a complex system composed of various landscape units, some of which were chosen for interdisciplinary studies. Bird nurseries, regionally called "ninhais," are a typical habitat of the Pantanal. These breeding colonies can comprise several thousand nesting birds and reveal an annual sequence of bird species breeding at the same places. The colonization of the nests is related to the annual variations of the water level. The use of food fish (e.g., *Eigenmannia* spp., *Synbranchus marmoratus*) as live bait by game-fishing tourists and the uncontrolled visitation of the bird rookeries threaten their existence (Oliveira and Da Silva 1998).

Because of the restricted area of the bird nurseries, the input of bird feces and dropped prey leads to an enormous concentration of nutrients in nearby lakes and groundwater (Girard and Pinto 2000). In the lake, conductivity, turbidity, nitrogen and phosphate compounds, dissolved oxygen, and water color are highly elevated during the low-water period (Abdo and da Silva 2002). This increase is attributed to water-volume reduction and the presence of birds (Oliveira and Da Silva 1998). Comparing this lake, which is close to the bird nursery, with others without nesting colonies showed that the aquatic birds play an important role in the dynamics of the lake nutrients (Abdo and da Silva 2002). The combination of satellite imagery and field observations aided the development of a scheme for identification of potential breeding sites to support conservation strategies for this important element of the Pantanal (da Silva et al. 2001a). Similarly, caimans control nutrient stocks in lakes (Nogueira et al. 2002b).

In lakes (e.g., Chacororé–Sinhá Mariana system), physical and chemical characteristics (da Silva and Esteves 1995) have been compared with species composition and distribution patterns of zooplankton (Morini 2000), phytoplankton (Loverde 2000), and benthic invertebrates (Butakka 2000). The density of invertebrates is rather low, and the highest biomasses of these organisms, which are important as a basis for fish production, are encountered in the margins (Butakka 2000). These large lakes have recently suffered because of the decreased water level of the Cuiabá River and other impacts. The data gathered by the PEP researchers serve as a basis for impact assessments.

Experimental and empirical studies on the isotopic composition of the food-chain members of lakes enable the food sources to be traced (Fellerhoff 2002, Wantzen et al. 2002). Fertilization experiments of mesocosms revealed the patterns of macrophyte–phytoplankton interactions and the "setting" of different competitive situations of these plants during the hydrological cycle (Adler and Junk 2002).

Vegetated earth mounds (capões) are an important shelter for terrestrial animals (both wild and bred) in the Pantanal during the flooding period. This causes a use conflict between ranching and conservation and makes ecological research efforts necessary. Origins of earth mounds were described and revised by Nunes da Cunha and Ponce (1993). The vegetation was characterized by Nunes da Cunha (1998) and Nunes da Cunha et al. (2002). To date, 16 mammal species and 64 bird species could be identified on a single earth mound (Oliveira et al. 1998). Light and malaise trapping revealed a high diversity of flying insects in the capões (Toledo 1999). A study of the dispersal mechanisms of tree species representative of the capão (Macedo et al. 1998) identified various types of diaspore dispersal: mainly ornithochory (75 percent), followed by anemochory and primatochory (18 percent each), and zoochory (12 percent). Most representative species were *Alibertia edulis, Ficus gardineriana, Ficus gomeleira,* and *Scheelea phalerata,* which are dispersed by birds and monkeys, the latter also by rodents.

An inundation gradient starting from the Piraim River (a tributary of the Cuiabá River) and continuing through a connected lake (Baia de Coqueiro), a floodplain area, a forest, a temporary water channel (Landi), and an unconnected lake that concentrates all the aquatic fauna during the dry season was identified

(Baia das Pedras; (Nogueira et al. 2002b). This gradient devoted intensive study to the relationship between groundwater and plant communities (Girard and Nunes da Cunha 1999, Ribeiro et al. 1999), decomposition of organic matter and nutrient cycling (Nogueira et al. 2002a, Bernardi 2001), the impact of cattle grazing on the biomass (Pozer 2002, Rebellato 2002), the limnological features (Nogueira et al. 2002b), the arthropofauna (Adis et al. 2001, Adis et al. *in press,* Marques et al. 2001), the avifauna (Pinho 2002), and the fish (Machado 2003, Wantzen et al. 2002).

Fisheries and tourism

The interface between ecology and economics is the validation of environmental goods, services, and attributes. The PEP aims to contribute to an ecological assessment of natural resources in order to show that sustainable management practices are not only ecologically correct, but also economically feasible for the entrepreneurs. Tourism has a high economic potential in the Pantanal, e.g., along the Transpantaneira park road. The socioeconomic status and the countries of origin of tourists were surveyed (Olivera 1999), and potential activities on ecotourism farms were registered (Garcia 2000). Often, fisheries and tourism are combined as game fishing, an issue much favored by the regional tourism boards. This has had negative effects on the local traditional fishermen communities, which are currently declining. The PEP researchers have evidenced the cultural importance of artisan fishing for the riverside populations (ribeirinhos) in the Pantanal (da Silva and Silva 1995), analyzed the techniques used (Porto 2000), and reviewed the current needs of the stakeholders (Silveira 2001). Artisan fishing is important as a food supply and as an economic factor for the local population, e.g., at the Bento Gomes River (Calegari and Nogueira 1998); however, fish stocks are insufficiently protected against bait fishing and habitat destruction by game fishers.

Many of the results have already been incorporated into environmental politics and policies. Limnological studies on the structure and function of the Pantanal lakes provided the basis of environmental impact analyses and juridical actions of the Public Ministry on the system containing Lakes Chacororé and Sinhá Mariana and the Cuiabá River. The studies on fish and fisheries provided data for the Legislative Assembly, the Public Ministry, and the State Council of the Environment to legislate on fisheries. Two PEP members (C. J. da Silva and F. A. Machado) were given awards for their efforts in conservation and defending the fishermen's rights by the State of Mato Grosso in 2001.

Studies on soil erosion and its impact on streams and gallery forests provided information to the project on agro-environment development for proposals for erosion control and recovery of gallery forests along headwater streams of the São Lourenço River (Rodrigues et al. 1999, Wantzen 2002).

Training of Personnel

Scientific education is one important pillar for the transfer of acquired knowledge to society. For the PEP, training of human resources also serves as a warranty for sustainability of the project. To date, 20 Brazilian and German doctorate theses have been completed in the cooperation and another five are ongoing. The graduate course on "Ecology and Conservation of Biodiversity" at the UFMT was substantially supported by the PEP and has been the most important tool for training young scientists. The use of most-recent results, specialized literature, and field infrastructure and equipment of the project benefits all students of the graduate course. Since 1994, 46 biologists who participated in this course obtained their Master's degrees, operating within the PEP; another 14 Master's studies within the PEP are in progress (see Figure 5). In the undergraduate program, students involved with the PEP wrote 81 monographs. Thus, over 60 percent of the Master's degrees and 25 percent of the Bachelor's degrees given by the Bioscience Institute of the UFMT during this period were linked with the PEP (see Figure 5). This education provides graduates with qualifications important for obtaining qualified employment. By May 2001, 16 graduates of the PEP were employed at universities, 11 were employed at governmental environmental agencies, 5 founded or were employed by private consulting agencies, 2 took graduate courses abroad, and 6 were in a doctoral program at a university in Brazil.

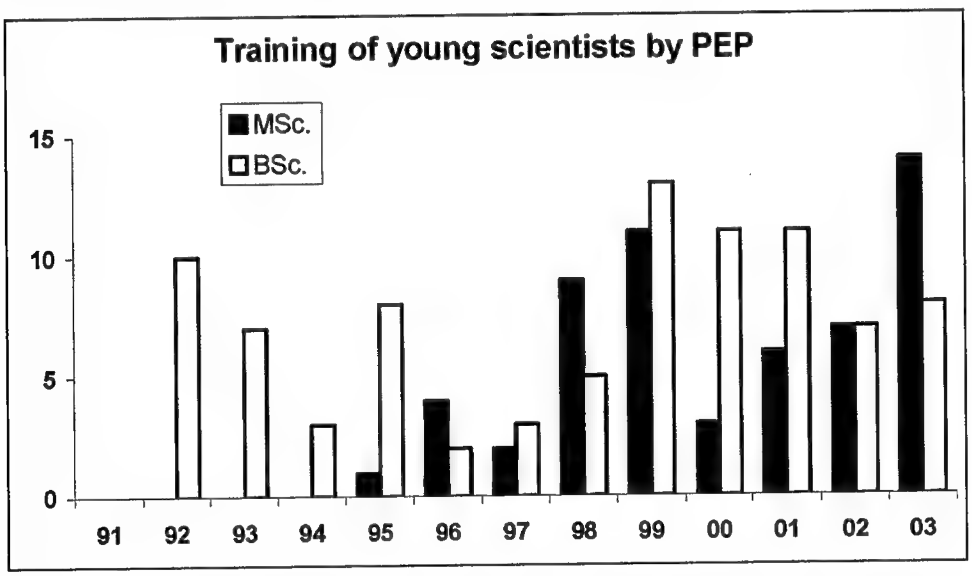

Figure 5. Master's and Bachelor's theses in ecology at the Federal University of Mato Grosso that were supported by the Pantanal Ecology Project. The Master's course on "Ecology and Conservation of Biodiversity" was established in 1994. Figures for 2003 include ongoing theses

Summary and Outlook

The Brazilian–German collaboration on the Pantanal has now become the intellectual nucleus for the establishment of the NEPA–Pantanal Ecology

Research Group of the Federal University of Mato Grosso. Current work concentrates on the effects of hydrological changes on biodiversity, abiotic patterns, and ecological processes. The staff includes ten Brazilian senior scientists, four German senior scientists, five technicians, and students at various levels.

The project established laboratories of international standard and trained scientists and technicians who are employed in the local labor market and will transfer their knowledge to different sectors of society. Today, the PEP is becoming increasingly involved in supporting environmental decision-making through management proposals (da Silva 2000, Junk 2000) and conservation planning (da Silva et al. 2001b). Scientific concepts are being extended or developed (Junk and da Silva 1999, Wantzen and Junk 2000, Junk and Wantzen 2003). Currently, the United Nations University has established a Pantanal Regional Environmental Program at the Federal University of Mato Grosso; this program is largely based upon the results of this fruitful cooperation. Within this context, future research activities on the effects of long-term hydrological variation on the Pantanal ecosystems are planned.

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About the Authors

Dr. Catia Nunes da Cunha is associate professor in the Federal University of Mato Grosso (UFMT) and Brazilian coordinator of the Pantanal Ecology Project (PEP). She is head of the NEPA - Pantanal Ecology Research Group at the UFMT. Her professional interests concentrate on ecology of wetland vegetation, ecological assessment for public and private organizations, and elaboration of management plans for natural reserves.

Dr. Karl Matthias Wantzen is the executive German coordinator of the PEP since 1994. He is currently research associate at the University of Konstanz. In the Pantanal and its catchments, he works on stream ecology, stable isotope analysis of foodwebs, decomposition of organic matter and tropical-temperate comparisons of freshwater ecosystems.

Dr. Wolfgang J. Junk is the German coordinator of the Pantanal Ecology Project and leader of the Tropical Ecology Work Group, at the Max-Planck-Institute for Limnology. He works on tropical wetland ecology, especially on aquatic botany, chemistry, concept development, conservation, and sustainable management in Amazonian and Pantanal floodplains.

8 Pantanal Tri-National GIS and Remote Sensing Pilot Project Case Study for Bolivia, Brazil, and Paraguay (*Estudo de Caso sobre o Projeto Piloto Tri-Nacional para o Desenvolvimento de SIG e Sensoreamento Remoto no Pantanal de Bolívia, Brasil e Paraguai*)

Kristine Kuhlman[1], Dawn Brown,[2] Montserrat Carbonell[2], and Carlos Roberto Padovani[3]

[1]Ph.D. Candidate, LICGF-University of Wisconsin, USA, e-mail: *kuhlman@unete.com*

[2]Ducks Unlimited Inc., Southern Regional Office, 193 Business Park Drive, Suite E, Ridgeland, MS 39157, USA, e-mail: *dbrowne@ducks.org*, *mcarbonell@ducks.org*

[3]Empresa Brasileira de Pesquisa Agropecuária – EMBRAPA-CPAP, Caixa Postal 109 – 79320-900 - Corumbá, MS, Brasil e-mail: *guara@cpap.embrapa.br*

Abstract (Resumo)

The Pantanal is the world's largest continuous freshwater wetland. Its boundaries extend across the borders of three countries: Bolivia, Brazil and

Paraguay, but more than 70 percent of the Pantanal is located in Brazil. All three countries protect discontinuous areas of the Pantanal. However, much of this region is still unprotected and mostly in private hands. After consultation with participating government agencies, research institutions, and individuals from the three countries, it became apparent that there is no comprehensive GIS database in place for the Upper Paraguay River Basin (UPRB). This short communication describes the standards and guidelines for delivering the GIS database, evaluating land use and conservation planning needs with natural resource management staff for the region, identifying a pilot project area, establishing data priorities, and formulating partnerships.

O Pantanal é a maior área úmida contínua de águas doces do mundo. Seus limites se estendem pelos territórios de Bolívia, Brasil e Paraguai, sendo que 70 porcento está contido em território brasileiro. Os três países têm áreas de proteção ambiental na região, as quais apresentam descontinuidade espacial. Contudo, grande parte da região ainda não é incluída em nenhuma unidade de conservação, mas situa-se em propriedades privadas. Este projeto se iniciou com consultas junto a agências governamentais, instituições de pesquisa e indivíduos dos três países, quando foi evidenciada a inexistência de um banco de dados que fosse baseado em um Sistema de Informações Geográficas (SIG) e que cobrisse toda a Bacia do Alto Rio Paraguai (BAP). Este artigo descreve os padrões e linhas gerais para o desenvolvimento de um banco de dados em SIG, avalia as demandas para o uso do solo e planos de conservação ambiental na região, identifica a área-piloto do projeto, estabelece prioridades de dados e propõe parcerias.

Key words

Remote sensing, GIS, Pantanal, wetland, conservation (*sensoreamento remoto, SIG, Pantanal, área úmida, conservação*)

Introduction

The completion of the Pantanal Tri-national Pilot Project in August 2003 is the initial step in the development of a comprehensive GIS and remote sensing database for conservation planning and a data distribution network for the Upper Paraguay River Basin (UPRB). The pilot area covers the region of the Otuquis (Bolivia), all of which is a newly dedicated Ramsar site, Nabileque (Brazil) that is soon to be designated Parque Estadual and a Ramsar site, and Río Negro (Paraguay) partly included in the Río Negro Ramsar site (Figures 1 and 2). Partners from governmental and non-governmental (NGO) agencies in Bolivia, Brazil, Paraguay and the United States have been collaborating on remote sensing and spatial data development tasks. Remotely sensed data were recognized as a vital application for studying inaccessible or remote areas at a regional scale and for change detection analysis. The data produced by the project will be used to model the effects of past, current, and future land-use practices and to determine boundaries of future protected areas or prioritize action for restoration in the UPRB.

The Pantanal is one of the world's richest ecosystems. Due to its location in the center of South America, it has fauna and flora typical of the Amazon, Chaco, Cerrado, Dry Chiquitania Forest, and Atlantic Forest ecosystems, which contribute to its high biological diversity. It includes more than 300 species of birds, 190 species of fish, 70 species of amphibians, and 50 species of large mammals (World Wildlife Fund (WWF) 2002). It is especially important for migratory birds and provides habitat for populations of giant river otter, marsh deer, tapir, and jaguar that are at risk in the region and elsewhere in the world (WWF 2002). See http://www.panda.org/livingwaters/fact3.htm). The Pantanal is the world's largest continuous freshwater wetland, approximately the size of Honduras, Nicaragua, and El Salvador combined, with an estimated area of 150,000 km^2, of which 110,000 km^2 are wetland (Scott and Carbonell 1986). Its boundaries extend across the borders of three countries: Bolivia, Brazil, and Paraguay, but more than 70 percent of the Pantanal is located in Brazil (Dolabella 2000). All three countries protect discontinuous areas of the Pantanal under different protection regimes such as the National Park Service, State Park Service, and Forestry Reserves. Some areas have also been designated as Ramsar sites under the Convention on Wetlands of International Importance especially as Waterfowl Habitat (Ramsar Convention, *http://www.ramsar.org*). However, much of this region is still unprotected and approximately 95 percent is under private ownership as cattle ranches (Crisman 2000) (See *http://www.pantanal.org/crisman.htm*). Primary threats to ecosystem health include road development projects, frequent uncontrolled fires, river channeling, and large-scale agriculture production, all of which can change the hydrology and water quality of the region.

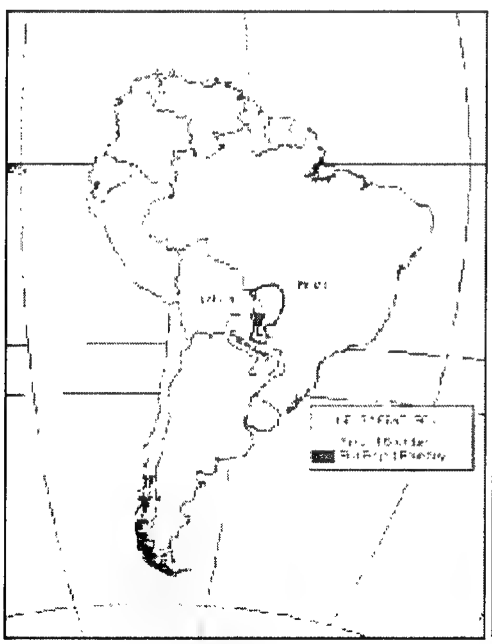


Figure 1. Study area, South America

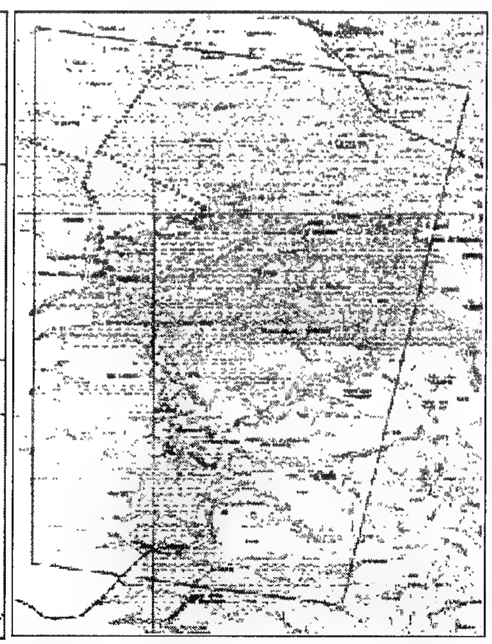


Figure 2. Close-up view of study area

Project Background

The challenge was to develop common, landscape-level data sets for tri-national natural resource planning. During the 7th Meeting of the Conference of the Contracting Parties to the Convention on Wetlands (Ramsar Convention) in Costa Rica, May (1999), Ducks Unlimited. Inc. (DU) and the USDA Forest Service organized a Geographic Information System (GIS) seminar to present DU's work with GIS on wetland and watershed protection over the last 20 years. After consultation with participating government agencies, research institutions and individuals from the three countries, it became apparent that there was no comprehensive GIS database in place for the Upper Paraguay River Basin (UPRB). Subsequently, a scoping meeting was held in Campo Grande, Mato Grosso do Sul, Brazil in April 2000 with the objectives of determining standards and guidelines for delivering a GIS and remote sensing database, evaluating land-use and conservation planning needs with natural resource management staff for the region, identifying a pilot project area, establishing data priorities, and formulating institutional partnerships.

Funded with seed money from the USDA Forest Service International Program, the role of DU has been one of facilitation and capacity building as well as coordinating fundraising efforts. DU and the USDA Forest Service are aware that a tri-national project can be complex and time-consuming, but the success of a project can only be guaranteed in the long term if the direct users of the results are involved and actively participating in the process.

The partnering organizations (and country) holding project agreements who have been actively involved in data development for the pilot project are listed below:

- World Wildlife Fund (WWF): Bolivia
- Fundação Estadual de Meio Ambiente (FEMA-MT): Brazil
- Instituto de Meio Ambiente Pantanal (IMAP-MS): Brazil
- Ecotrópica: Brazil
- Universidade Católica Don Bosco (UCDB): Brazil
- Empresa Brasileira de Pesquisa Agropecuaria (EMBRAPA): Brazil (in the process of signing agreement)
- Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis (IBAMA): Brazil (in the process of signing agreement)
- Fundación Moisés Bertoni (FMB): Paraguay
- Guyrà (Birdlife International): Paraguay
- University of Memphis: USA
- LICGF-University of Wisconsin: USA
- US Geological Survey: USA
- USDA Forest Service: USA

- Ducks Unlimited Inc.: USA
- Ducks Unlimited Canada: Canada

Description of Results

One of the purposes of the change detection analysis for the pilot area was to determine landscape level changes, both natural and human-induced, for the Pantanal pilot project area so cross-border analyses could be made and common methods could be applied for planning, monitoring and managing the basin. In the past, each country has completed many projects that have generated important spatial information for the Upper Paraguay River Basin. However, each used different classification schemes and a variety of formats, even within their own country, making data sharing and transfer extremely difficult. To counter this challenge, the Pantanal Pilot GIS project partners decided to start with several analyses that are important for conservation. Several approaches were used to identify temporal change in the following analyses:

Hydrology (Figure 3).

- Seasonal Flooded Area/Water Level Changes (Max/Min flooded area)

Historical Landscape Change.

- Human-induced (NDVI/vegetation change).
- Naturally occurring (fires and regeneration) burn scars.

Roads Data Update.

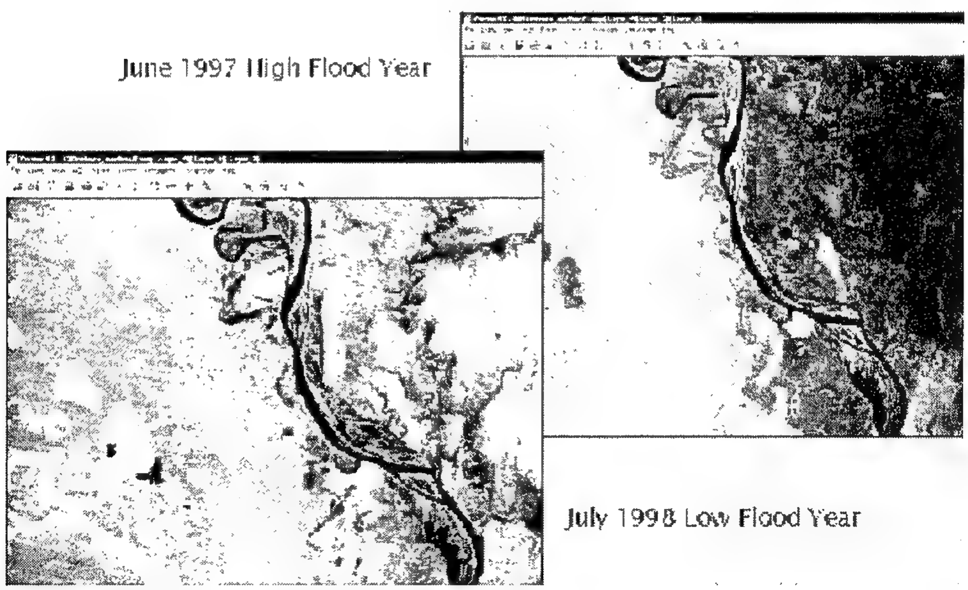


Figure 3. Seasonal Flooded Area/Water Level Changes (Max/Min flooded area)

The group also decided to use ERDAS Imagine image processing software and ESRI's GIS products, including ArcView 3.2, ArcView Spatial Analyst, and

ArcView Image Analysis to develop a long-term solution that will unite the three countries in their desire to protect and manage the Pantanal.

The use of Landsat TM (Thematic Mapper) and Landsat ETM+ (Enhanced Thematic Mapper) satellite imagery was a logical choice for monitoring and evaluating environmental threats in the pilot project area and eventually the entire Upper Paraguay River Basin for the following reasons:

- Each image covers a large regional area (185x170 km/scene).
- The spatial resolution provides sufficient detail for landscape studies (30x30 meter/picture element).
- Scenes are captured frequently and archived.
- Multi-spectral characteristics allow features such as vegetation, moisture, and inundation to be extracted from the data.
- The use of this technology provided a cost-effective method for landscape scale analysis.

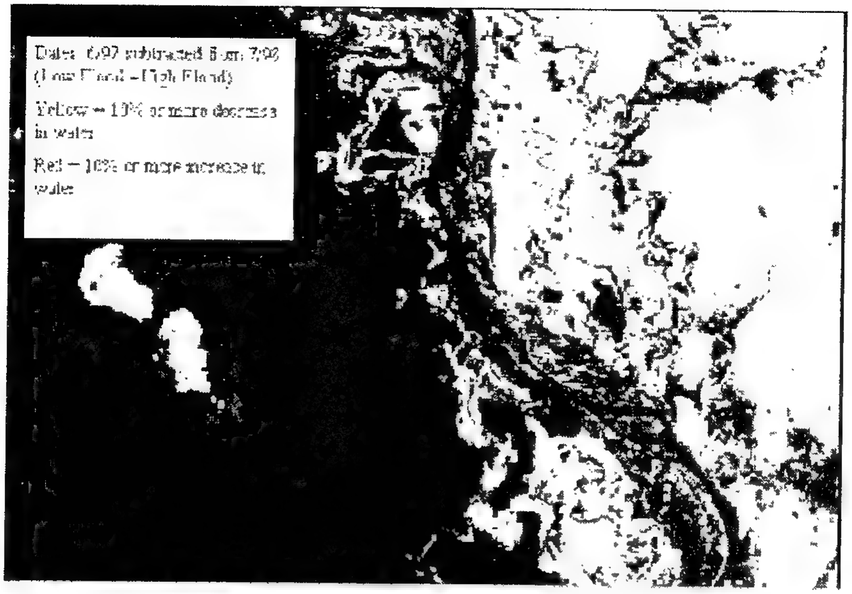
Based on river gauge and precipitation information gathered from several sources in South America, Landsat TM and ETM+ scenes and dates were selected for the pilot area. River height and/or discharge data were evaluated to determine the optimal timing for the satellite imagery. The Pantanal has widely variable water flooding regimes both seasonally and annually within the basin. It is very important to understand this variability when selecting imagery for change detection analysis. Precipitation data are important for the same reasons. Timing of rainfall in the pilot area sub-region must be well understood to apply it to the selection of imagery.

The following imagery dates were used for this study and represented high, medium, and low water periods as well as high fire seasons:

- Landsat TM -June 9, 1997
- Landsat TM -July 7, 1998
- Landsat TM - November 19, 1998
- Landsat TM - December 24, 1999
- Landsat TM – November 23, 1988
- Landsat ETM+ - November 14, 1999

Utilizing ERDAS Imagine and ESRI software, partners from Bolivia, Brazil, and Paraguay have been working together on image processing and GIS data development tasks such as edge detection, normalized difference vegetation index (NDVI), differencing flood extent analysis (Figure 4), multi-temporal burn scar and flood data layers, and updating digital roads data. Satellite imagery and aerial photography can also be used in conjunction with wildlife surveys and other GIS feature data for habitat assessments. The data produced by these assessments can be used to model the effects of current and future land-use practices and determine, for example, boundaries of future protected areas or areas of priority action for restoration. It can also be used to make management

decisions at sub-catchment levels and it offers planners and decision-makers the tools necessary to provide sustainable alternatives to development projects.



Use ERDAS Imagine's Change Detection Utility to difference the binary files for different dates A highlighted "change file" is produced. Dates: 6/97 subtracted from 7/95 (Low Flood – High Flood)

Figure 4. Change detection differencing flood extent analysis

As a result of coordinated software training and brainstorming at various workshops and field data collection efforts between and within the three countries, the following pilot project deliverables were developed and presented in draft format for review at a meeting in Cuiabá, Brazil in August 2002:

- A GIS data and satellite imagery inventory for the pilot area.
- An imagery-based change detection dataset depicting areas with significant change in the last 10+ years (1) Seasonal Flood Extent, (2) Vegetation/NDVI, (3) Multi-date burnscar data layers.
- Analysis and map production at a landscape level.
- Updated roads coverage for the pilot project portion in each country.
- Land cover maps and other existing topographic maps for each country have been compiled, reprojected, and mosaicked where scale and format permitted.
- Compilation of existing georeferenced historical aerial photography for portions of the pilot area and acquisition of new aerial photography with GPS coordinates for Bolivia, Paraguay, and Brazil.
- Fieldwork producing ground control points (GCP's) for georeferencing of imagery (Figure 5).

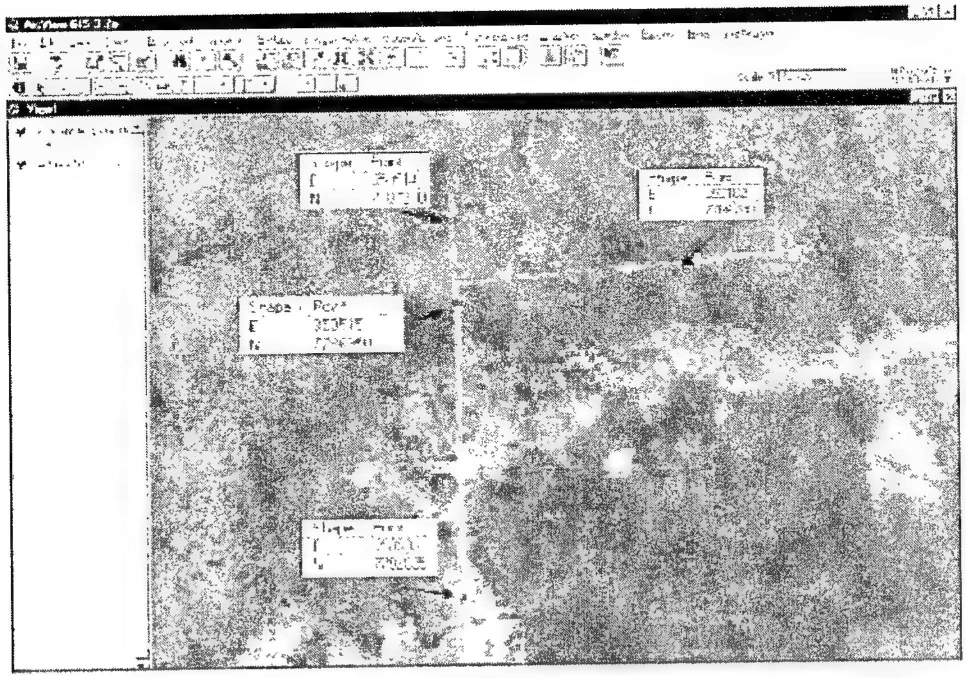


Figure 5. Ground control points (GCP's) for georeferencing of imagery

- Quality check of the data that have been collected to ensure that the three countries have compatible file formats, projections, and attributes.
- A standardized metadata format has been completed for all datasets.
- A report and PowerPoint presentation documenting procedures and the contents of the database are in the final stages of development.
- A team of local organizations with GIS capacity in Bolivia, Brazil, and Paraguay will continue to develop and maintain the integrated database for the entire Upper Paraguay River Basin.

In addition to the above contributions to the development of the Pantanal GIS database, the project has also produced the following benefits:

- Establishment of a technical network of professionals specialized in GIS, remote sensing, and spatial data development.
- Development of a Pantanal GIS email discussion list with more than 200 members for posting messages and updates related to the Pantanal GIS project, as well as other Pantanal projects.
- Building of alliances between institutions and countries sharing stewardship of the Upper Paraguay watershed.
- Coordination and standardization of applications and procedures among the three countries for the development, maintenance, and use of the comprehensive Upper Paraguay River Basin GIS database.
- The preliminary results of a proposed tri-national land cover classification for the UPRB.
- The project has been documented in journals and newspapers.

Initial findings show that time-series NDVI and NDVI differencing appeared to produce the best results for visually detecting landscape-scale, clear-cut and burned areas in forest and heavily vegetated areas. A decrease in the infrared coupled with an increase in red leads to a large decrease in the calculated NDVI for a burn scar compared to that of unburned vegetation. The rationale of this procedure is that it highlights areas showing a change in time, normally associated with fire damages and vegetation re-growth. The decorrelated data produced through this process were of great value in enhancing regions of localized change in NDVI.

Data Distribution

The completion of the pilot project leads to the next phase of GIS database development, which includes (1) web-enabling the pilot project data inventory, (2) expanding the project to other areas in the UPRB, and (3) confirming a location and organization responsible for establishing, maintaining, and serving the database. Satellite imagery will continue to play an essential role in the development of key datasets and identifying priority areas of monitoring, evaluation, and planning. At present, a communication and dissemination strategy is being developed to ensure that these data may be made available to both technicians and planners. An effective way to share the pilot project results and attract more users of the database is via the Internet. There are three main Internet-based components:

- Create a Metadata (data description) Clearinghouse - soon to be served through the US Geological Survey site (*http://130.11.52.184/servlet/FGDCServlet*) where the general public will have access.

- Develop a GIS data and literature inventory – a data inventory and bibliography was compiled in Access at DU and will be served via a web-enabled data catalogue created and maintained by Ducks Unlimited, Canada. The general public will not have access yet.

- Compile the database for ftp access and Internet – develop, test, and establish an initial central location for all project-related GIS and imagery data and documents. Mirror sites may be developed later. The general public will not have access yet.

The institutional capabilities of the partners for housing and serving the Pantanal GIS project database were evaluated as well as outside organizations who already have this capability and whose mission is to serve conservation data. These organizations were assessed to determine which groups were the most viable candidates in terms of their technical capabilities, staffing resources, and administrative partnership requirements or restrictions. A final decision on server location and data distribution methods is pending. The data will be stored and maintained in a database located at DU headquarters in Memphis, TN until a server location is finalized.

Conclusions

The methods and standards established during the pilot project will be transferred to the broader Upper Paraguay River Basin Tri-National GIS project. The image processing methods may vary slightly for each country depending on software availability, landscape characteristics, hydrology, and other factors that make various portions of the Pantanal unique. New partners will inevitably join the project and the technical capabilities and software/hardware availability of each new partner will vary. Many suggestions were made during the pilot project on how to expand on some of the image processing and GIS tasks. Communication between partners via meetings and the technical discussion list will continue to be pivotal to the technical development of the project.

From the Pilot Project to the Comprehensive Upper Paraguay River Basin

The completion of the pilot project leads to the next phase of GIS database development, which includes:

- Expanding the project to other areas in the UPRB.
- Web-enabling the pilot project data inventory for the general public.
- Confirming the location/s and organization/s responsible for establishing, maintaining and serving the database.

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9 Integrated River Management in the Pantanal: The Need for Decision Support Systems (*Gestão Integrada de Recursos Hídricos no Pantanal: O Papel de Sistemas de Apoio à Tomada de Decisão*)

Dr Rob H.G. Jongman
Alterra, Wageningen University and Research Centre, PO Box 47,
6700 AA Wageningen, The Netherlands e-mail: *Rob.jongman@wur.nl*

Abstract (*Resumo*)

The Pantanal is part of the Upper Paraguay River Basin (UPRB). The major driving force of the wetland system is the annual oscillation between dry and wet seasons. The water flow reaches very low speeds, due to a very gentle slope in the east-west and north-south direction. One of the rivers is the Taquari, about 800 km long. Coxim is the border between 'Bacia do médio e baixo Taquari' (Pantanal) and 'Bacia do alto Taquari' (BAT) in the highlands.

The upper reaches of the Rio Taquari represent one of the major erosive areas of the highlands around the Pantanal, consisting of sandy soils. This erosive character has resulted in an inundated area of 11.000km^2 in the lower reach of the Taquari. In the lower Taquari, major developments have an impact on the economic sustainability of farming and have placed increased pressure on biodiversity, resulting in a decline of important plant species. Communication in the river basin is difficult due to the scarce population, long distances, and the

lack of roads. There is a lack of knowledge about the consequences of land use upstream for biodiversity, land use downstream, and the functioning of the river.

To solve these problems a well-organized water management system at the level of the river basin is needed. A Brazilian-Dutch project has been developed that includes plans to build a river management decision support system (DSS) similar to that developed for the Rhine Catchment in Europe.

O Pantanal é parte da Bacia do Alto Paraguai (BAP) e suas características naturais são principalmente decorrentes de oscilações anuais entre a estação seca e a estação chuvosa. O fluxo natural de água alcança velocidades relativas muito baixas, devido a inclinações muito suaves no relevo de leste a oeste e do norte a sul. Um dos principais rios do Pantanal é o Taquari, com aproximadamente 800 quilômetros de extensão. A cidade de Coxim tem importância estratégica por estar situada no limite entre a sub-bacia do Alto Taquari (BAT), na zona de planalto, e a sub-bacia do Médio e Baixo Taquari, na zona de planície (que é o Pantanal propriamente dito).

A sub-bacia do Alto Taquari é formada basicamente por solos arenosos e de grande erosividade. O aumento de sedimentos devido à intervenção humana no planalto é responsável por severa alteração no regime de inundação numa área de 11.000 km^2 *no Baixo Taquari (planície). Outra questão ambiental importante está associada à crescente pressão sobre a biodiversidade, resultanto em declínio de algumas espécies. A causa principal tem sido a dificuldade econômicas por que passa a pecuária regional. A difusão de informações junto às comunidades locais é dificultada devido à baixa densidade demográfica, às longas distâncias e à falta de estradas regulares. Há ainda uma carência de conhecimentos científicos a respeito de conseqüências de intervenções no planalto sobre biodiversidade, solos de planície e funcionamento hidrológico.*

Com o propósito de contribuir para a solução de tais questões, é necessario um sistema gestão de recursos hídricos organizado ao nível de bacia hidrográfica. Uma parceria Brasil-Holanda foi estabelecida e um de seus objetivos é desenvolver um sistema de apoio à tomada de decisão (DSS) para a gestão do Rio Taquari, semelhante ao que foi desenvolvido para a Bacia do Reno na Europa.

Key words (*Palavras—Chave)*

Integrated river management, decision support system, Pantanal (*gestão integrada de bacias hidrográficas, sistema de suporte à tomada de decisões, Pantanal*)

Introduction

The Pantanal is the world's largest continuous freshwater wetland. Its sustainability is of utmost importance for the local and regional economies, the water supply, and the environment. However sustainability is not guaranteed. Its boundaries extend across the borders of Bolivia, Brazil, and Paraguay. The Pantanal is situated in the Upper Paraguay River Basin (UPRB). The processes

that take place are dominated by the water dynamics in the UPRB. Development and management of the Pantanal is impossible without an understanding and evaluation of the whole river basin. This means that international scientific cooperation and development of mutually coordinated policy are important for maintaining the system as a whole.

The objective of the Brazilian-Dutch project is to develop a better understanding of the impact that human influences have on the Pantanal basin and to be able to understand the functioning of the UPRB as a whole. This will assist in developing more sustainable use of the water systems in the UPRB and sustainable land use of the Pantanal. Identifying policy options and management strategies will be a key outcome of this research, ensuring strong links between ecological research, land use aspects, technology, management, and policy. The project will help to:

- Identify opportunities for economically feasible productivity and limits to sustainable production; therefore, research will analyze natural and agro-resource use systems at local and/or regional levels.

- Develop sustainable water management at river-basin scale and address an increasing efficiency in water use, innovative multi-purpose utilization, control of sediment load, erosion, control of private use, pollution and water logging and supply/resource management at basin level in order to meet competing demands including upstream and downstream effects of land use, erosion, and sedimentation.

Water Management in Brazil and the Upper Paraguay River Basin (UPRB)

In the last five years within the Brazilian Parliament the issue of water management has received strong attention, especially because of the large strategic freshwater supplies that are available in the region. In Brazil new water resource legislation has been in place since 1997 (Ministry de Meio Ambiente, Secretariat of Water Resources, 2002).The objectives are:

- To ensure that present and future generations have necessary access to water of adequate quality for various uses.

- To ensure the rational and integrated use of water resources,..., in order to achieve sustainable development.

- To prevent and protect against water critical events of either natural origin or caused by inappropriate use of natural resources.

The water resources legislation provides guidelines for systematic water management with adjustment to physical, biotic, demographic, economic, and cultural differences among the various regions, and coordination of water resources management with that of land use.

In Brazil the water management system is in an early stage of development. This system contains the National and State Councils of Water Resources, River Basin Committees, Water Agencies, and civil water resources organizations. The Secretariat of National Water Resources is responsible for the formulation of the National Water Resources Policy and the National Water Agency is the federal body that implements this policy.

Technical knowledge on the behavior of river systems is in an early stage of development. The legislation mentions the need for developing long-term water resource plans and River Basin Committees representing all interests. This is comparable with, but far less elaborate than the provisions in the EU-water directive (European Parliament and European Commission 2000). The water resource plans are master plans for river basins containing a diagnosis of the water resources, an analysis of users and population growth, identification of potential conflicts, priorities for granting water-use rights and guidelines for water-use fees. The plans have to be approved and monitored by river basin committees consisting of representatives of federal, state, and municipal authorities, water users and civil water resource entities. In several areas these plans are under development. All these plans need baseline data and a related monitoring system. Support to develop these plans requires knowledge that is largely lacking. The Taquari project can support the organization of a river basin committee by developing a baseline.

The Brazilian government recognizes the need for direct problem solving and the setup of a water management system at the river basin level. In the Programa Pantanal the general objective for the intermediate term is the stabilization of the environmental quality of the Pantanal's ecosystems. The long-term objective is the use of natural capital for sustainable economic activities, considering the human, economic, and ecological dimensions. It is developed under the responsibility of the federal Ministry of the Environment with the Executive Secretariat as general coordinator. The Program has three sub-executors: the Brazilian Institute for the Environment and Natural Resources, the State of Mato Grosso, and the State of Mato Grosso do Sul through their Environmental Institutes. Research is not the main objective of the Programa Pantanal. The program emphasizes development of sustainable institutions and efficient sustainable management of the ecosystems in the Pantanal. However, specific research is needed to define the direction of development and to provide tools for decision-making and management.

One of the agendas of the Programa Pantanal is the Blue Agenda focusing on (Figure 1):

- Water management.
- River basin management.
- Restoration of critical micro-watersheds.
- Control of mining activities.
- Restoration of the Taquari River Basin.

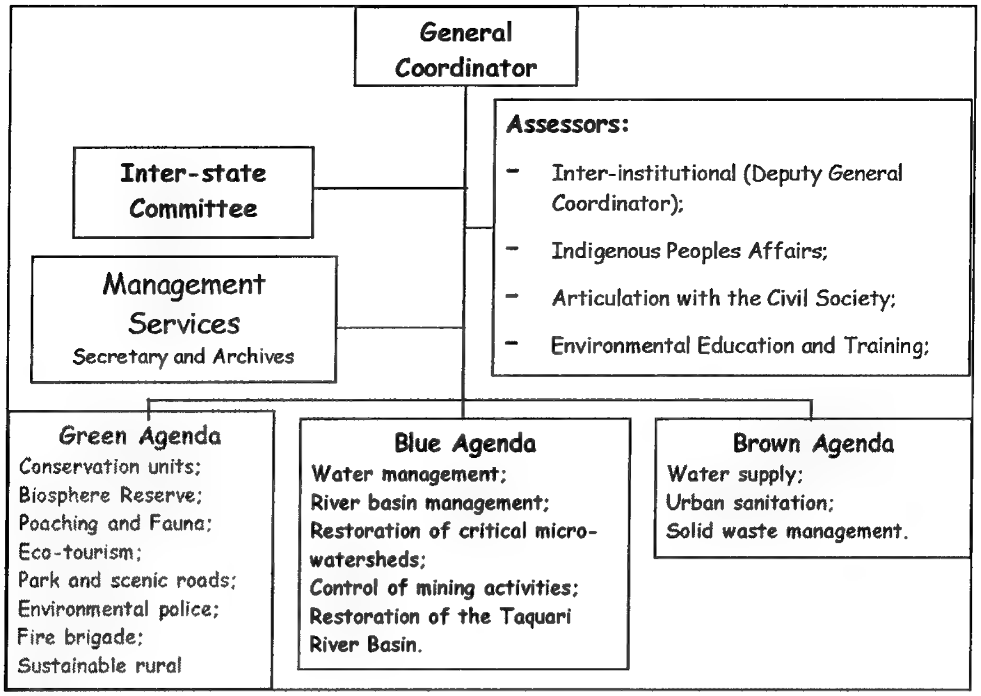

Figure 1. Structure and working fields of the Programa Pantanal (simplified)

One of the major challenges of the Programa Pantanal is the development of scientific and technical capacity in river management and the organization of sustainable river management at a river basin scale. There is at the moment a lack of expertise on developing knowledge systems for integrated land and water management in this region. The Taquari project is aiming to fill that gap.

Water Management in the Taquari River Basin

The objectives of the Brazilian government are to promote sustainable and socially accepted water resource management policies (Ministerio de Meio Ambiente 2002). Developing sustainable water management requires insight into the functioning of the system of the Pantanal and coherent data that can be used for policy and scenario development. This project aims to contribute to the development of sustainable use of the Pantanal by:

- Developing *insight in the hydrological and land use system of the UPRB* to enhance sustainable water management for the Pantanal and the UPRB as a whole, including socio-economic developments, national policies, and policy options for the Taquari basin.

- Providing insight for policymakers and stakeholders on priorities and consequences of management options and strategies for the Pantanal.

Integrated river basin policy requires joint scientific knowledge and collaboration between science and policy-making. Understanding the ecosystem dynamics of the Pantanal is essential for developing a more sustainable use of its renewable natural resources (water fish, biodiversity). The Brazilian-Dutch

research project in the Taquari aims to identify policy options and management strategies for the sustainable use of these resources, ensuring a strong link between technical management and policy research.

The project will identify opportunities for sustainable use of the river basin as well as its limits based on the existing and newly required data (Ministerio de Meio Ambiente 1997). The research project addresses an integrated approach and analysis of natural, agro-resource use and fishery systems at the river basin level. The aspects of integrated management include control of sediment load, erosion pollution and water logging, water resource management at the basin level in order to meet the sustainability of the system, and repairing and preventing the downstream effects of upstream land use.

Land-use development in and especially around the Pantanal is getting out of balance. Erosion in the uplands, mining, pollution, economic problems for cattle farming, and a decline of biodiversity in several parts of the wetland system threaten the future of the Pantanal. Sustainable development is possible only if joint river management is developed.

The knowledge gained in this project can be applied outside the Taquari as well, because the structure of the Pantanal is comparable to other basins. Methods and insight developed in the Pantanal might be transferable to other basins. There will, of course, still be differences because of increasing complexity and interference between systems, and because the development of the Pantanal as a whole is also based on hydrology, hydraulics, biodiversity priorities, sustainable cattle breeding, fishing, and ecotourism.

Present Situation and Project Objectives

Over 70 percent of the Pantanal is located in Brazil. It is the largest complex of wetlands in the world – it is part of the UPRB and it comprises an area of 595,230 km^2, of which 363,460 km^2 fall within Brazil, with the remaining section in Bolivia (121,360 km^2) and Paraguay (110,410 km^2). It is made up of 10 large rivers, alluvial fans, lagoons, fossil dunes, and salt pans. The Brazilian section of UPBR can be divided into two main areas: floodplains or Pantanal and high plateaus or Planalto. In Brazil the Pantanal is a declared UNESCO world natural heritage site. It consists of a part that is influenced by the River Paraguay, large areas that are dominated by the river regime of the tributaries of the Paraguay, and several ancient parts characterized by a precipitation-dependent system of baias and salinas (Dantas et al 1999, Assine and Soares 2003). Most of the region is in private possession and unprotected. In Bolivia about 2 million hectares are protected and declared Ramsar sites (San Matias and Otuquis). Many organizations develop actions for protection, development, and management of parts of the Pantanal. Coordinating land use, biodiversity conservation, and water management is only in early stages of development or totally lacking. An important technical issue is the lack of effective transboundary data management (Kuhlman and Padovani 2003).

The major natural driving force of the wetland system of the Pantanal is the annual oscillation between dry and wet seasons that takes place in the UPRB (Junk et al. 1989, Junk and Da Silva 1995, Da Silva et al. 2001). The Pantanal collects precipitation water as well as water from the uplands (Planalto) around it. Water flows at very low speeds, due to a very gentle slope, which is essential for bringing in nutrients and attracting a wide range of fauna. The different subbasins and the Paraguay River are in permanent interaction. Groundwater movements and the role of groundwater in the Pantanal system are largely unknown.

In general, erosion and sedimentation processes are important in river systems. A factor influencing the erosion process in the Taquari is the change in the precipitation pattern in the last 30 years. Analysis of precipitation based on available data over the period of 1969-89 for Brazil shows a dry period in the years 1969-73 and a wet period in 1974-89, with average precipitations of 1.254 mm and 1.581 mm, respectively (Soriano et al. 2001). There has been more discharge and also an increase in precipitation during the last decades that may be related to natural oscillations or to man-induced climatic changes (Figure 2).

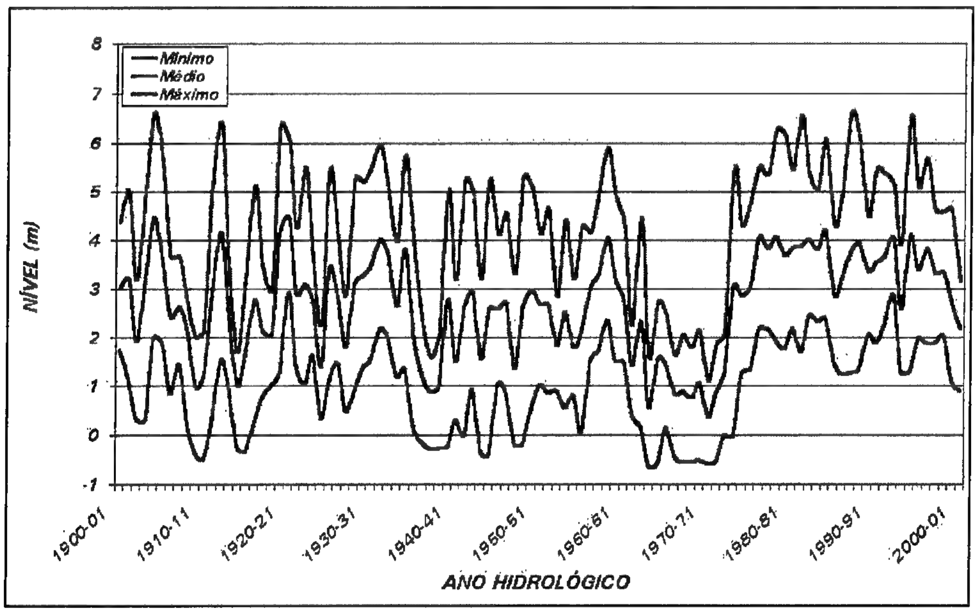

Figure 2. Oscillations in water level in the Rio Paraguay in the last century (Soriano et al. 2001) (Upper line: mean highest annual water level, middle line: mean annual water level, lower line: mean lowest annual water level)

However, this is only part of the reason for the change in discharge. Human intervention and the impact of climate change must also be considered. Since the 1970s a program has been developed in Brazil to combat poverty in the densely populated southern regions. Many people moved north in the internal colonization. They changed the vegetation of the cerrado east of the Pantanal into grassland and cultivated land (mostly soy). The cultivation of the Planalto since the 1970s has strongly changed the vegetation cover of the Planalto (Table 1). The removal of the native vegetation in the highlands of the Serra de Pantanal and Serra de Maracaju (350-600 m asl) has severe consequences for the rivers

going into and through the Pantanal. In several catchments such as the high Taquari River basin, the soil is highly erosive. Therefore the internal colonization might have led to an unexpected environmental impact on large portions of the Pantanal or the Pananal as a whole (Figure 3). There are also indications that the hydrological regime is changing in the catchment as a whole. This could be related to global climate change (Collischon et al 2001).

Table 1
Vegetation Change in the Bacia do Alto Taquari (BAT-Planalto) (Oliveira et al. 2000)

Vegetation Change	1974	1984	1991
Annual crops (%)	2.0	6.9	11.4
Cultivated grassland (%)	1.4	35.5	41.6
Native vegetation (%)	96.6	57.6	47.0

Erosion and discharge change are also occurring in several other catchments in the UPRB in Brazil, Bolivia, and Paraguay. Erosion and siltation transform the major rivers into unstable anastomosing systems. In the Taquari system (80,000 km^2) this causes a more or less permanent inundation of an area of 11,000 km^2. This leads to economic and ecological problems due to increasing flooding with potentially serious threats for fauna, flora, fisheries, and cattle breeding and in this way for the whole economy of the UPRB. Knowledge of the hydrological system, including erosion and sedimentation, is a key issue in understanding and managing the Pantanal.

Current world market prices are creating pressure to expand cattle breeding, especially on natural grassland systems such as the Pantanal. This is causing farmers to look for alternative sources of income by trying to intensify their farming practices. In the Pantanal, farms also have to grow in order to maintain economic profitability. Farms below 10,000 ha do not seem to be economically viable any more (Cadavid Garcia 1986). This means that farms are increasing in size and farmers are trying to find ways to increase their production. (The cattle density is currently about 0.25 units per hectare.) This increases pressure on biodiversity, and leads to a decline of important plant species. Water pollution from agrochemicals impacts fish, birds, and alligators in particular. Alternative income for farmers now comes mostly from ecotourism and fisheries. Sport fishing is one of the major sources of income in the Pantanal (60,000 persons/year).

Fish biodiversity, healthy fish populations, and sport fishing depend on a healthy aquatic environment. Persistence of flood pulses is likely essential (Junk et al. 1989, Neiff 1999). Maintaining the Pantanal as a seasonal savannah is therefore a major objective to maintain its biodiversity, its function for cattle breeding, and its attraction for fishing and ecotourism. Changing the river system into a permanent flooded area, as occurs now in the lower Taquari basin, has a strong impact on the biodiversity and the size of the fish populations. Changes in the river regime and especially flooding will also influence cattle ranging and probably also N_2O and N_2 fluxes (Augustin et al. 2002). Clearly, changes in hydrodynamics due to human and/or natural causes can have significant long-

term impacts on the whole region, because economy, biodiversity, and social life are mutually inter-dependent within this river and wetland system. This Brazilian-Dutch project allows comparisons between the disturbed and undisturbed (permanently flooded) rivers.

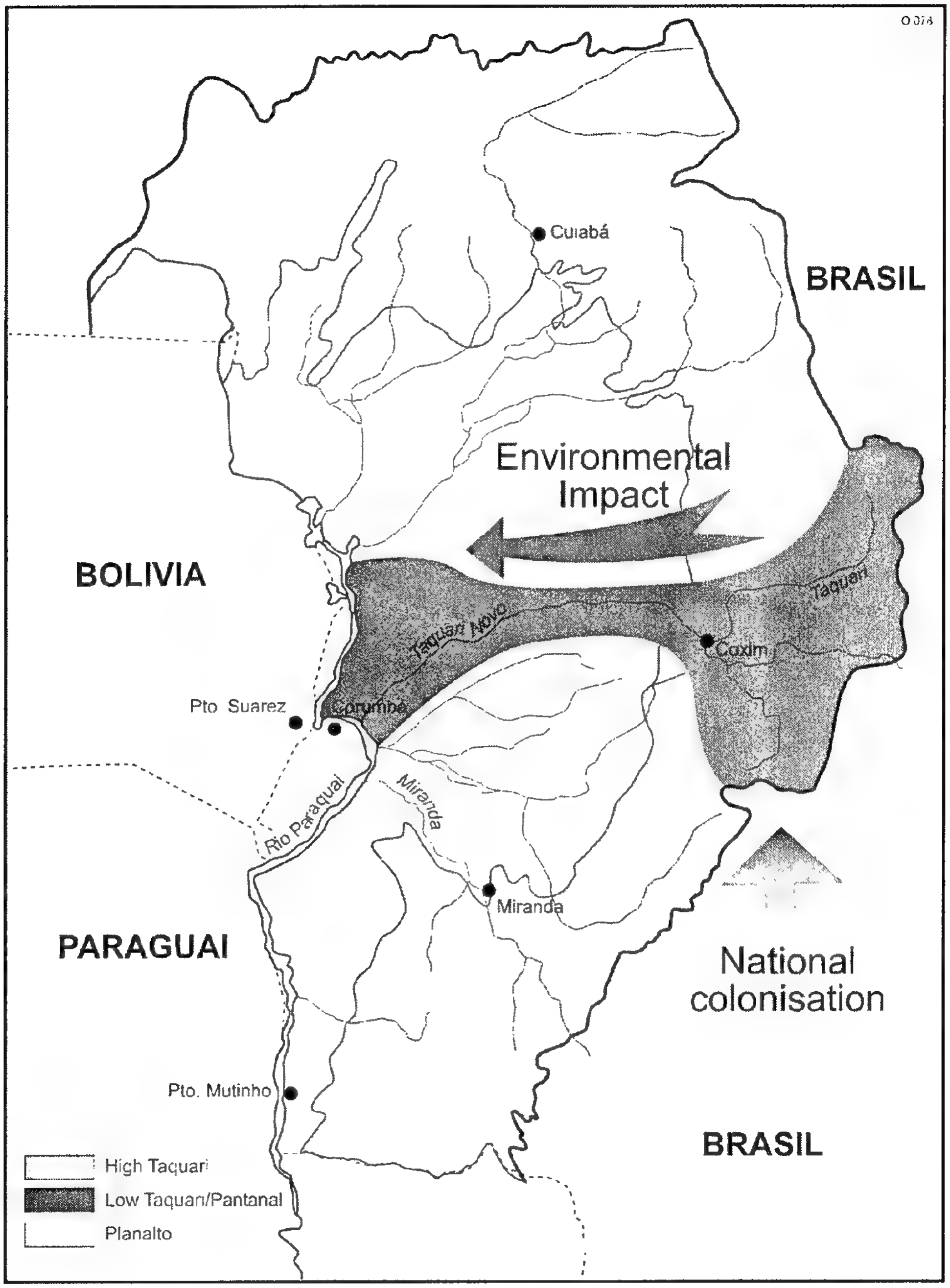

Figure 3. Possible spatial impact of the internal colonization on the Taquari River basin due to increased erosion

In the tri-national pilot project on conservation of the Pantanal, research institutes and non-governmental organizations from Brazil, Bolivia, and Paraguay have developed a common GIS database in cooperation with Canadian and U.S. NGO's (Brown et al. 2003). The pilot area covers the region of Otuquis

(Bolivia), Nabileque (Brazil), and Rio Negro (Paraguay). This is only a pilot information system at the moment and the big step forward will be its expansion to the whole of the UPRB and linking it with models and scenarios. The modeling in the Taquari basin and the setup of a spatial database will make it possible for decision makers and river managers to use knowledge on the system as a tool in the management and policy decision-making process. Where legislation and management systems and plans are lacking, a coherent system of data, models, and scenarios can help to provide insight to support the setup of plans and commissions.

Discussion

To be sustainable, rational water use must balance human requirements with the needs to support biodiversity, incorporating concerns at the regional, national, and international levels. At the international and national levels, the Pantanal is viewed as a prime biodiversity area. The Brazilian-Dutch Taquari project delivers the coherent knowledge for this policy and can provide the knowledge to develop a coherent policy for integrating biodiversity conservation with water policy and rural land use.

Socio-economic issues must be addressed. For large wetland areas, economic viability is pivotal for the feasibility of biodiversity conservation, cattle production, and water management. As the development of river-basin-based water management is in an early stage of development in Brazil, the Brazilian-Dutch project is of utmost importance to build a knowledge system for integrated water management. It will facilitate international cooperation in order to resolve the major issues in water management and biodiversity conservation. It also will support, scientifically and technologically, water and river basin research and strengthen the research systems in Brazil.

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About the Author

Dr. Rob Jongman is a landscape ecologist with long experience in river ecology, landscape planning, and environmental monitoring. His Ph.D. project was on ecology and policy making in river systems (Rhine). From 1995 until 1999 he worked on modeling the landscape and the role of water in the Orinoco and Pantanal. At the moment, he is coordinating a project on river management in the Pantanal.

Glossary of Acronymns

Acronym	Portuguese Definition	English Definition
ABRH	Associação Brasileira de Recursos Hídricos	Brazilian Association of Water Resources
ANA	Agência Nacional de Águas	National Water Agency
ATTZ	Zona de Transição Aquático-Terrestre	Aquatic Terrestrial Transition Zone
BAP/UPRB	Bacia do Alto Rio Paraguai	Upper Paraguay River Basin
BAT	Bacia do Alto Taquari	Upper Taquari Basin
BOD/DBO	Demanda Biológica de Oxigênio	Biological Oxygen Demand
CAPES	Coordenação de Aperfeiçoamento de Pessoal de Nível Superior	Coordination for the Improvement of High Education Personnel
CHL	Laboratório de Ciência Marítima e Hidráulica	Coastal and Hydraulics Laboratory
CIDEMA	Consórcio Intermunicipal para o Desenvolvimento Integrado das Bacias dos Rios Miranda e Apa	Intermunicipal Consortium for the Integrated Development of the Miranda and Apa River Basins
CIDEPAN	Consórcio Intermunicipal para o Desenvolvimento do Pantanal	Intermunicipal Consortium for the Development of the Pantanal
CNPq	Conselho Nacional de Desenvolvimento Científico e Tecnológico	National Council for Scientific and Technological Development
CPAP	Centro de Pesquisa Agropecuária do Pantanal	Center of Agricultural Research for the Pantanal
DAEE	Departamento de Águas e Energia Elétrica	Sao Paulo Water Agency
DDT	Dicloro-difenil-tricloroetano (inseticida)	Dichloro-diphenyl-trichloroethane (pesticide)
DF	Distrito Federal, Brasil	Federal District, Brazil
DLR	Agência Espacial da Alemanha	German Space Agency
	(Deutsches Zentrum für Luft- und Raumfahrt)	
DNOS	Departamento Nacional de Obras e Saneamento	National Department of Works and Sanitation
DU	Ducks Unlimited (ONG)	Ducks Unlimited
DSS	Sistema de Apoio à Decisão	Decision Support System
EC	Comissão Européia	European Commission
EDIBAP	Plano de Desenvolvimento Integrado da Bacia do Alto Parwaguai	Study for the Integrated Development of Upper Paraguay Basin
EL	Laboratório Ambiental	Environmental Laboratory
EMBRAPA	Empresa Brasileira de Pesquisa Agropecuária	Brazilian Agriculture Research Facility
ERDC	Centro de Pesquisa e Desenvolvimento em Engenharia	Engineer Research and Development Center
ESRI	Instituto de Pesquisa em Sistemas Ambientais	Environmental Systems Research Institute, Inc.

Acronym	Portuguese Definition	English Definition
ETM+	Mapeador Temático Ampliado (Landsat)	Enhanced Thematic Mapper (Landsat)
EU	União Européia	European Union
FEMA	Fundação Estadual de Meio Ambiente	State Environmental Agency
FPC	Conceito de Pulso de Inundação	Flood Pulse Concept
GCP	Pontos de Controle em Solo	Ground Control Points
GDP/PIB	Produto Interno Bruto	Gross Domestic Product
GEF	Fundo Ambiental Mundial	Global Environment Facility
GIS/SIG	Sistema de Informações Geográficas	Geographic Information System
HDI/IDH	Índice de Desenvolvimento Humano	Human Development Index
IAHS	Associação Internacional de Ciências Hidrológicas	International Association of Hydrological Sciences
IB	Instituto de Biociências, UFMT	Biosciences Institute, UFMT
IBAMA	Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis	Federal Agency for Conservation and Management of Renewable Natural Resources
ICV	Instituto Centro de Vida	Institute Center of Life
IDB	Banco Interamericano de Desenvolvimento	Inter-American Development Bank
IMAP	Instituto de Meio Ambiente – Pantanal	Pantanal Institute of the Environment
IDRC / CIID	Centro Internacional de Pesquisa para o Desenvolvimento	International Development Research Center
IUCN	União Internacional para a Conservação da Natureza	International Union for the Conservation of Nature
IWRB	Wetlands International (ONG)	International Waterfowl and Wetlands Research Bureau (now called Wetlands International)
IWRN	Rede Inter-Americana de Recursos Hídricos	Inter-American Water Resources Network
MG	Minas Gerais (estado)	Minas Gerais (state)
MMA	Ministério do Meio Ambiente	Ministry of the Environment
MPIL	Instituto Max-Planck de Limnologia	Max-Planck-Institute of Limnology
MS	Mato Grosso do Sul (estado)	Mato Grosso do Sul (state)
MT	Mato Grosso (estado)	Mato Grosso (state)
NDVI	Índice Normalizado de Diferença de Vegetação	Normalized Difference Vegetation Index
NEPA	Núcleo de Estudos Ecológicos do Pantanal	Center of Ecological Studies of the Pantanal
NGO/ONG	Organização Não Governamental	Non-Governmental Organization
NUPAUB	Núcleo de Apoio à Pesquisa sobre Populações Humanas e Áreas Úmidas Brasileiras	Center of Research on Human Populations and Wet Areas in Brazil
OAS/OEA	Organização dos Estados Americanos	Organization of American States
PCBAP	Plano de Conservação da Bacia do Alto Paraguai	Upper Paraguay River Basin Conservation Plan
PEP	Projeto de Ecologia do Pantanal	Pantanal Ecology Project
PHPP	Projeto Hidrovia Paraguai/Paraná	Paraguay/Parana Hidrovia Project
PNMA	Programa Nacional do Meio Ambiente	National Environmental Program
PREP	Programa Regional Ambiental do Pantanal	Pantanal Regional Environmental Program
PRODEPAN	Programa Especial para o Desenvolvimento do Pantanal	Special Program for the Development of Pantanal
PRODOESTE	Programa para o Desenvolvimento do Centro Oeste	Program for the Development of Centre-West

Acronym	Portuguese Definition	English Definition
PRONABIO	Programa Nacional da Diversidade Biológica	National Program for Biological Diversity
SEMACT	Secretaria Estadual de Meio Ambiente, Cultura e Turismo	Secretariat of the Environment, Culture and Tourism
SHIFT	Estudos sobre os Impactos Humanos em Florestas e Planícies de Inundação nos Trópicos	Studies of Human Impacts on Forests and Floodplains in the Tropics
SOUTHCOM	Comando do Sul (Exército Norte Americano)	Southern Command (U.S. Army)
SRH	Secretaria de Recursos Hídricos (Ministério do Meio Ambiente)	Secretariat of Water Resources (Ministry of the Environment)
SUDECO	Superintendência para o Desenvolvimento do Centro Oeste	Superintendency for the Development of the Brazilian Centre-West Region
TM	Mapeado Temático (Lansat)	Thematic Mapper (Landsat)
UCDB	Universidade Católica Don Bosco	Catholic University of Don Bosco
UNB	Universidade de Brasília	University of Brasília
UFMG	Universidade Federal de Minas Gerais	Federal University of Minas Gerais
UFMT	Universidade Federal de Mato Grosso	Federal University of Mato Grosso
UMFS	Universidade Federal de Mato Grosso do Sul	Federal University of Mato Grosso do Sul
UFScar	Universidade Federal de São Carlos	Federal Unversity of Sao Carlos
UN/ONU	Organização das Nações Unidas	United Nations
UNDP/PNUD	Programa das Nações Unidas para o Desenvolvimento	United Nations Development Program
UNEMAT	Unversidade Estadual de Mato Grosso	State University of Mato Grosso
UNESCO	Organização das Nações Unidas para a Educação, Ciência e Cultura	United Nations Educational, Scientific and Cultural Organization
UNINCOR	Universidade Vale do Rio Verde de Três Corações	University of Rio Verde de Três Corações Valley
UPRB/BAP	Bacia do Alto Rio Paraguai	Upper Paraguay River Basin
USDA	Ministério da Agricultura dos Estados Unidos	United States Department of Agriculture
WOTS	Apoio Técnico Operativo a Recursos Hídricos	Water Operations Technical Support
WWF	Fundo para a Conservação da Natureza	World Wildlife Fund for Nature

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14. ABSTRACT
The Pantanal is one of the largest complexes of wetlands in the world, and has justifiably received increasing international attention. The Pantanal supports an extraordinary diversity and abundance of wildlife, making this "great swamp" a globally significant center of biological diversity. Critical to the maintenance of this natural diversity is the historical pattern of seasonal flooding that also affects economic activities in the region — cattle ranching, commercial and sport fishing, and ecotourism. Agricultural development in the surrounding Cerrado and proposals to improve navigation along the Paraguay River are environmental issues of particular concern within the region. While the socio-economic and ecological stability of the Pantanal depends largely on maintaining the integrity of the annual flood pulse, the hydro-ecology of the region is still poorly understood. The Pantanal Program was established by Brazil in 2001 to foster sustainable development in the Upper Paraguay River Basin. The long-term goal is to effectively employ natural capital in sustainable economic development that equally considers human, economic, and ecological dimensions. The purpose of the symposium was to exchange information of mutual interest on innovative approaches to enhancing environmental sustainability in a large, complex ecosystem. A group of renowned scientists, resource managers, and public officials involved in the Pantanal Program were brought together to discuss the past, present, and future of stewardship in the Pantanal. The papers presented here address a full spectrum of ecological, socio-economic, and socio-political issues relevant to the Pantanal.
(Continued)

15. SUBJECT TERMS
Brazil (*Brasil*)
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14. ABSTRACT

O Pantanal é uma dás áreas úmidas de maior complexidade no mundo, o que tem justificado crescente atenção internacional. A região pantaneira apresenta extraordinária diversidade e exuberante vida silvestre, tornando este "imenso pântano" um centro de biodiversidade de importância global. Suas características naturais são críticas para a manutenção da diversidade natural e do regime sazonal de inundação, o que significativamente influencia as atividades econômicas na região – produção de gado, pesca comercial e profissional, e ecoturismo. A expansão agrícola nas áreas vizinhas de cerrado e propostas como o incremento da navegação ao longo do Rio Paraguai são questões ambientais que despertam especial preocupação.

Enquanto a sócio-economia e a estabilidade ecológica do Pantanal dependem, em grande medida, da integridade do pulso anual de cheias, a hidro-ecologia da região é ainda pouco compreendida. O Programa Pantanal do Ministério do Meio Ambiente do Brasil foi iniciado em 2001 com o objetivo de promover o desenvolvimento sustentável da Bacia do Alto Rio Paraguai. Seu propósito de longo prazo é a utilização de capital natural num modelo de desenvolvimento sustentável que justa e apropriadamente considere as dimensões humana, econômica e ecológica.

A proposta deste simpósio foi facilitar a troca de experiências em iniciativas inovadoras que buscam aumentar a sustentabilidade ambiental em extensos e complexos ecossistemas. Foi convidado um grupo de renomados cientistas, gestores ambientais e representantes governamentais para discutir o passado, presente e futuro da proteção do Pantanal. Os trabalhos aqui apresentados descrevem um amplo espectro de temas ecológicos, sócio-econômicos e sócio-políticos que demonstram ser altamente relevantes para o Pantanal.